EXHIBIT 10

US006958451B2

(12) **United States Patent**
Breed et al.

(10) **Patent No.: US 6,958,451 B2**
(45) **Date of Patent: Oct. 25, 2005**

(54) **APPARATUS AND METHOD FOR MEASURING WEIGHT OF AN OCCUPYING ITEM OF A SEAT**

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(73) Assignee: **Automotive Technologies International, Inc.**, Denville, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 67 days.

(21) Appl. No.: **10/174,803**

(22) Filed: **Jun. 19, 2002**

(65) **Prior Publication Data**

US 2003/0056997 A1 Mar. 27, 2003

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/901,879, filed on Jul. 9, 2001, now Pat. No. 6,555,766, which is a continuation of application No. 09/849,559, filed on May 4, 2001, which is a continuation-in-part of application No. 09/193,209, filed on Nov. 17, 1998, now Pat. No. 6,242,701, which is a continuation-in-part of application No. 09/128,490, filed on Aug. 4, 1998, now Pat. No. 6,078,854, which is a continuation-in-part of application No. 08/970,822, filed on Nov. 14, 1997, now Pat. No. 6,081,757, and a continuation-in-part of application No. 08/474,783, filed on Jun. 7, 1995, now Pat. No. 5,822,701, application No. 10/174,803, which is a continuation-in-part of application No. 09/849,559, which is a continuation-in-part of application No. 09/193,209, which is a continuation-in-part of application No. 09/128,490, which is a continuation-in-part of application No. 08/970,822, and a continuation-in-part of application No. 08/474,783, application No. 10/174,803, which is a continuation-in-part of application No. 09/849,558, filed on May 4, 2001, now Pat. No. 6,653,577, which is a continuation-in-part of application No. 09/193,209, which is a continuation-in-part of application No. 09/128,490, which is a continuation-in-part of application No. 08/970,822, and a continuation-in-part of application No. 08/474,783, application No. 10/174,803, which is a continuation-in-part of application No. 09/770,974, filed on Jan. 26, 2001, now Pat. No. 6,648,367, and a continuation-in-part of application No. 09/767,020, filed on Jan. 23, 2001, now Pat. No. 6,533,316, and a continuation-in-part of application No. 09/753,186, filed on Jan. 2, 2001, now Pat. No. 6,484,080, application No. 10/174,803, which is a continuation-in-part of application No. 09/500,346, filed on Feb. 8, 2000, now Pat. No. 6,442,504, which is a continuation-in-part of application No. 09/128,490, which is a continuation-in-part of application No. 08/970,822, and a continuation-in-part of application No. 08/474,783.

(51) **Int. Cl.**^{7} **B60R 21/32**

(52) **U.S. Cl.** **177/1**; 177/144; 702/101; 180/273; 280/735; 701/45

(58) **Field of Search** .... 701/45; 702/101, 702/102; 180/273; 280/735; 177/136, 144, 210 R, 1

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,275,975 A	9/1966	King	180/272
4,519,652 A	5/1985	Kamijo	180/268

(Continued)

FOREIGN PATENT DOCUMENTS

EP	950560	10/1999	177/144
EP	0990565	4/2000	

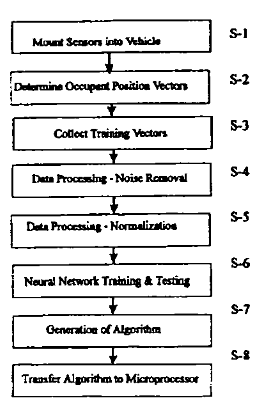
(Continued)

Primary Examiner—Randy W. Gibson
(74) *Attorney, Agent, or Firm*—Brian Roffe

(57) **ABSTRACT**

Arrangement and method for determining weight of an occupying item in a seat including one or more weight sensors arranged to obtain a measurement of the force applied to the seat, a forcing function determination arrangement for measuring a forcing function of the seat and a processor coupled to the weight sensor(s) and forcing function determination arrangement for receiving the measurement of the force applied to the weight sensor(s) and the measurement of the forcing function from the forcing function measurement system and determining the weight of the occupying item based thereon. The forcing function determination arrangement may include an accelerometer and measures effects on the seat caused by load of a seatbelt associated with the seat and/or effects on the seat of road roughness, steering maneuvers, and a vehicle suspension system.

39 Claims, 36 Drawing Sheets



U.S. PATENT DOCUMENTS

4,625,320 A		11/1986	Butcher	382/104
4,639,872 A		1/1987	McHale et al.	364/463
4,645,233 A		2/1987	Bruse et al.	280/753
4,698,571 A		10/1987	Mizuta et al.	318/466
4,811,226 A		3/1989	Shinohara	318/466
4,907,153 A		3/1990	Brodsky	364/424.05
5,008,946 A		4/1991	Ando	180/167
5,071,160 A		12/1991	White et al.	280/735
5,074,583 A		12/1991	Fujita	280/735
5,086,652 A		2/1992	Kropp	73/767
5,090,493 A		2/1992	Bergan et al.	177/211
5,118,134 A		6/1992	Mattes	280/735
5,125,686 A		6/1992	Yano	280/801.2
5,155,685 A		10/1992	Kishi et al.	364/424.05
5,161,820 A		11/1992	Vollmer	280/730
5,222,399 A		6/1993	Kropp	73/862.68
5,232,243 A		8/1993	Blackburn et al.	280/735
5,254,924 A		10/1993	Ogasawara	364/424.05
5,330,226 A		7/1994	Gentry et al.	280/735
5,377,108 A		12/1994	Nishio	701/45
5,413,378 A		5/1995	Steffens, Jr. et al.	280/735
5,439,249 A		8/1995	Steffens, Jr. et al.	280/735
5,454,591 A		10/1995	Mazur et al.	280/735
5,474,327 A		12/1995	Schousek	280/735
5,531,472 A		7/1996	Semchena et al.	280/735
5,573,269 A		11/1996	Gentry et al.	280/735
5,583,771 A		12/1996	Lynch et al.	701/45
5,653,462 A		8/1997	Breed et al.	280/735
5,670,853 A		9/1997	Bauer	318/286
5,691,693 A		11/1997	Kithil	340/439
5,694,320 A		12/1997	Breed	364/424.055
5,702,123 A		12/1997	Takahashi et al.	280/735
5,714,695 A		2/1998	Bruns	177/211
5,732,375 A	*	3/1998	Cashler	701/45
5,748,473 A		5/1998	Breed et al.	364/424.055
5,785,347 A		7/1998	Adolph et al.	280/735
5,802,479 A		9/1998	Kithil et al.	701/45
5,821,633 A		10/1998	Burke et al.	307/10.1
5,822,707 A		10/1998	Breed et al.	701/49
5,829,782 A		11/1998	Breed et al.	280/735
5,844,486 A		12/1998	Kithil et al.	340/573
5,848,802 A		12/1998	Breed et al.	280/735
5,918,696 A		7/1999	Van Voorhies	180/273
5,927,427 A		7/1999	Sewell et al.	180/273
5,942,695 A		8/1999	Verma et al.	73/768
5,943,295 A		8/1999	Varga et al.	367/99
5,948,031 A		9/1999	Jinno et al.	701/45
5,957,491 A		9/1999	Cech et al.	280/735
5,973,273 A	*	10/1999	Tal et al.	177/1
5,979,585 A		11/1999	Van Voorhies	180/273
5,984,349 A		11/1999	Van Voorhies	280/735
5,991,676 A		11/1999	Podoloff et al.	701/45
6,015,163 A		1/2000	Langford et al.	280/735
6,021,863 A		2/2000	Stanley	180/273
6,039,344 A		3/2000	Mehney et al.	280/735
6,045,155 A		4/2000	Cech et al.	280/735
6,056,079 A	*	5/2000	Cech et al.	180/273
6,069,325 A		5/2000	Aoki	177/136
6,076,853 A		6/2000	Stanley	280/735
6,087,598 A		7/2000	Munch	177/144
6,104,100 A		8/2000	Neuman	307/10.1
6,109,117 A		8/2000	Stanley et al.	73/862.325
6,161,439 A	*	12/2000	Stanley	73/862.391
6,161,891 A		12/2000	Blakesley	296/65.01
6,218,632 B1		4/2001	McCarthy et al.	177/144
6,231,076 B1		5/2001	Blakesley et al.	280/735
6,253,134 B1		6/2001	Breed et al.	701/49
6,259,042 B1	*	7/2001	David	177/136
6,259,167 B1	*	7/2001	Norton	307/10.1
6,260,879 B1		7/2001	Stanley	280/735
6,286,861 B1		9/2001	Cech et al.	280/735
6,808,200 B2	*	10/2004	Drobny et al.	280/735
6,808,201 B2	*	10/2004	Aoki	280/735

FOREIGN PATENT DOCUMENTS

GB	2289332	11/1995	280/735
GB	2333070	7/1999	
GB	2340252	2/2002	
WO	9825112	6/1998	
WO	0112473	2/2001	
WO	0113076	2/2001	

* cited by examiner

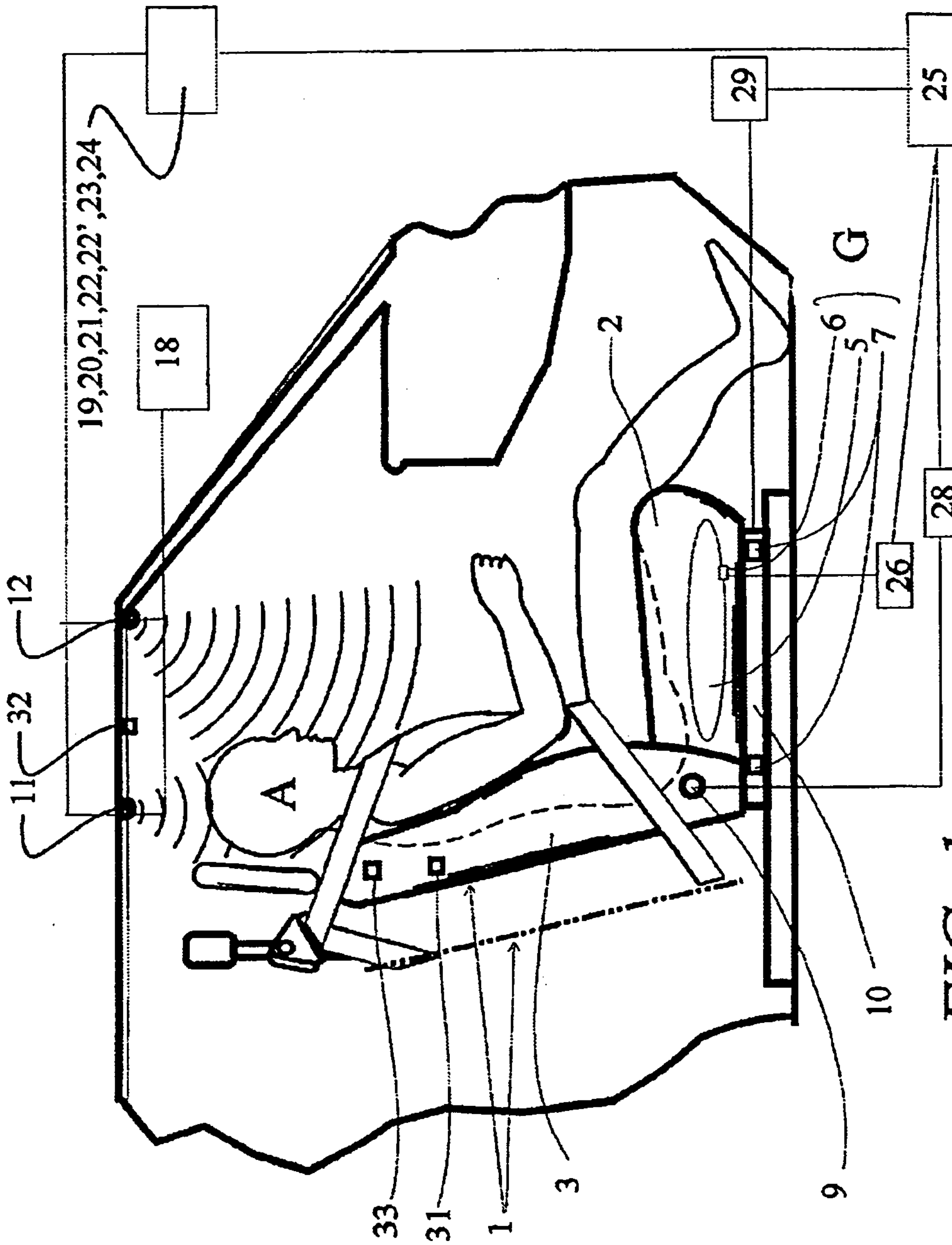


FIG. 1

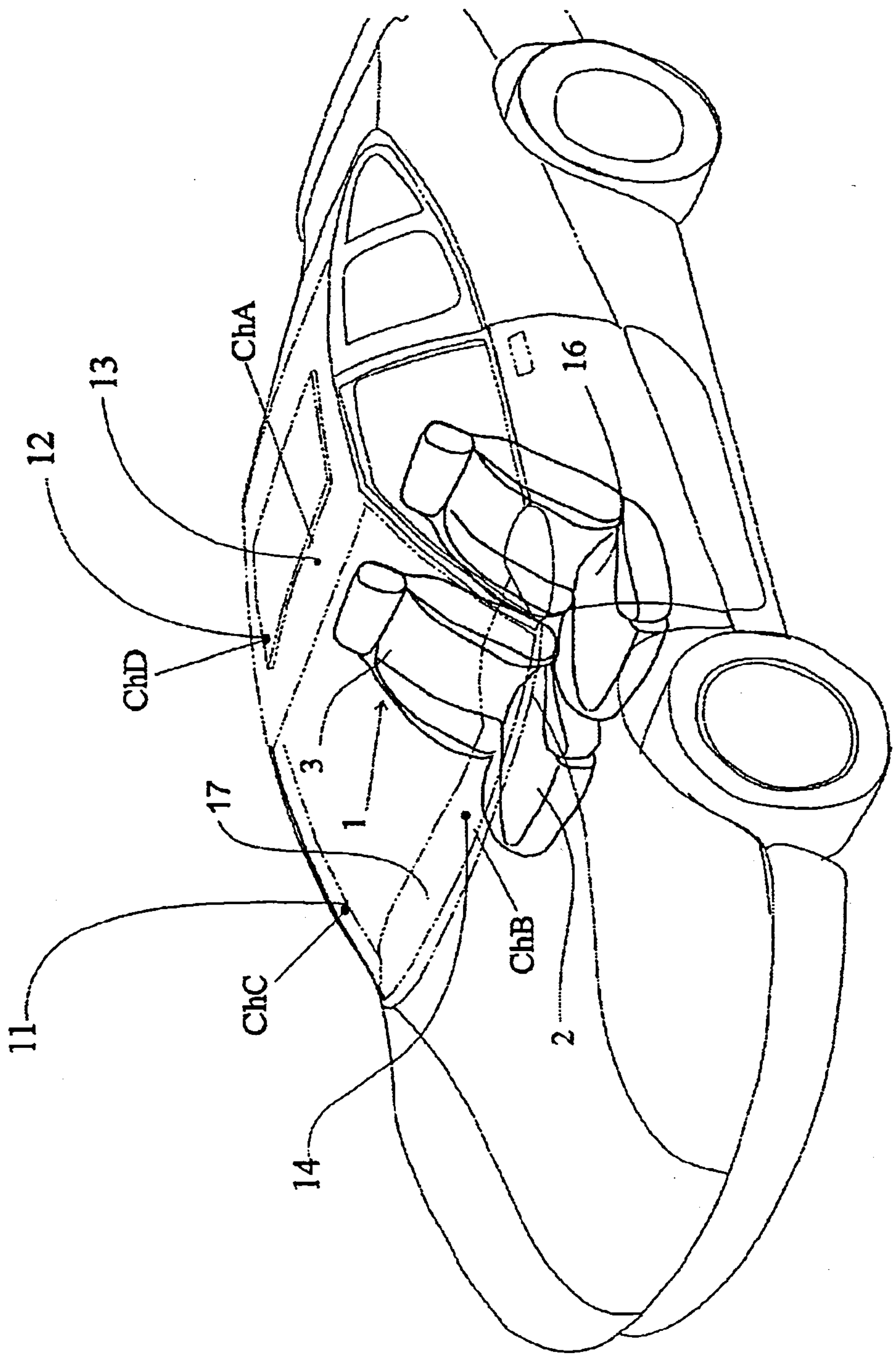


FIG. 2

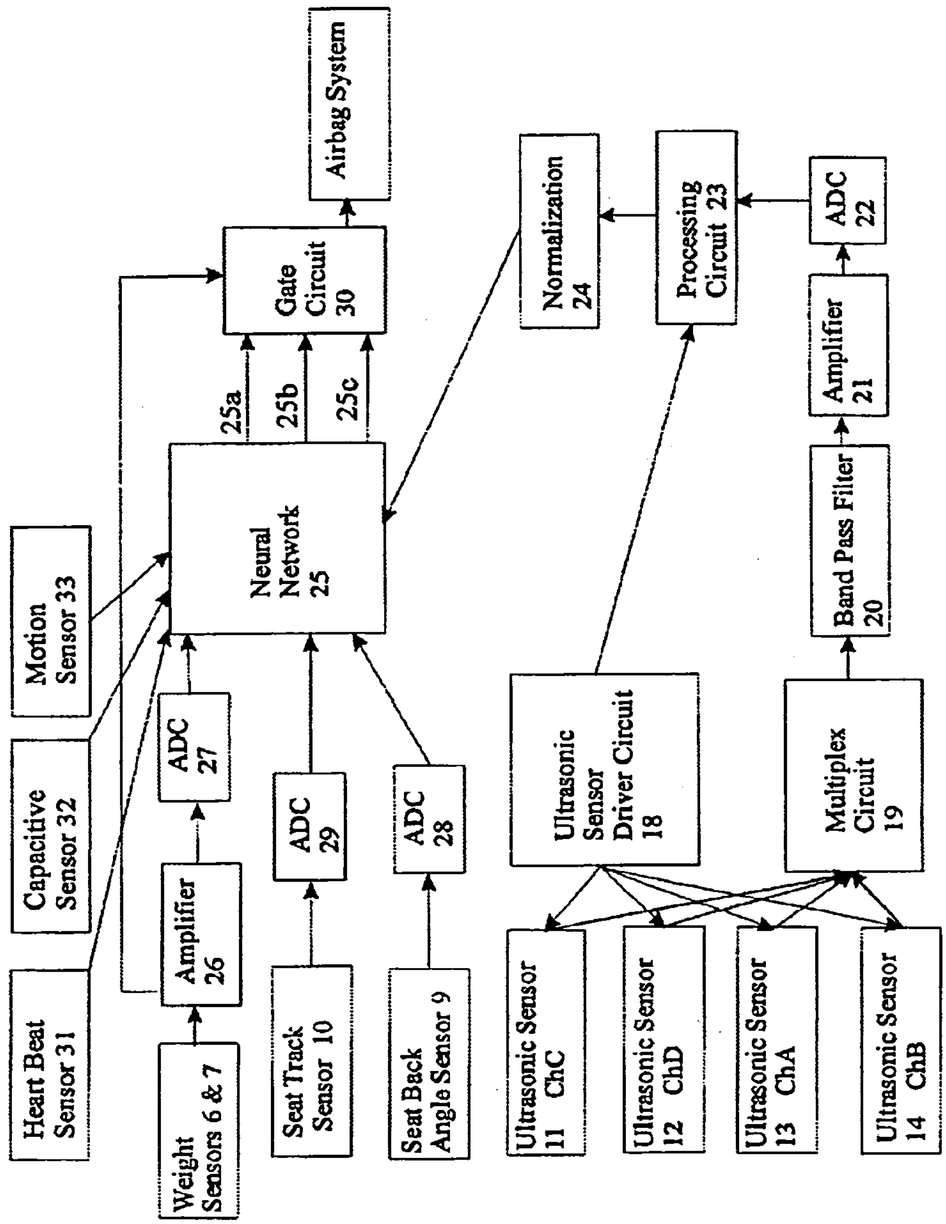

Airbag System
Gate Circuit 30
25a
25b
25c
Neural Network 25
Normalization 24
Processing Circuit 23
ADC 22
Amplifier 21
Band Pass Filter 20
Motion Sensor 33
Capacitive Sensor 32
Heart Beat Sensor 31
ADC 27
Amplifier 26
Weight Sensors 6 & 7
ADC 29
Seat Track Sensor 10
ADC 28
Seat Back Angle Sensor 9
Ultrasonic Sensor Driver Circuit 18
Multiplex Circuit 19
Ultrasonic Sensor 11 ChC
Ultrasonic Sensor 12 ChD
Ultrasonic Sensor 13 ChA
Ultrasonic Sensor 14 ChB

FIG. 3

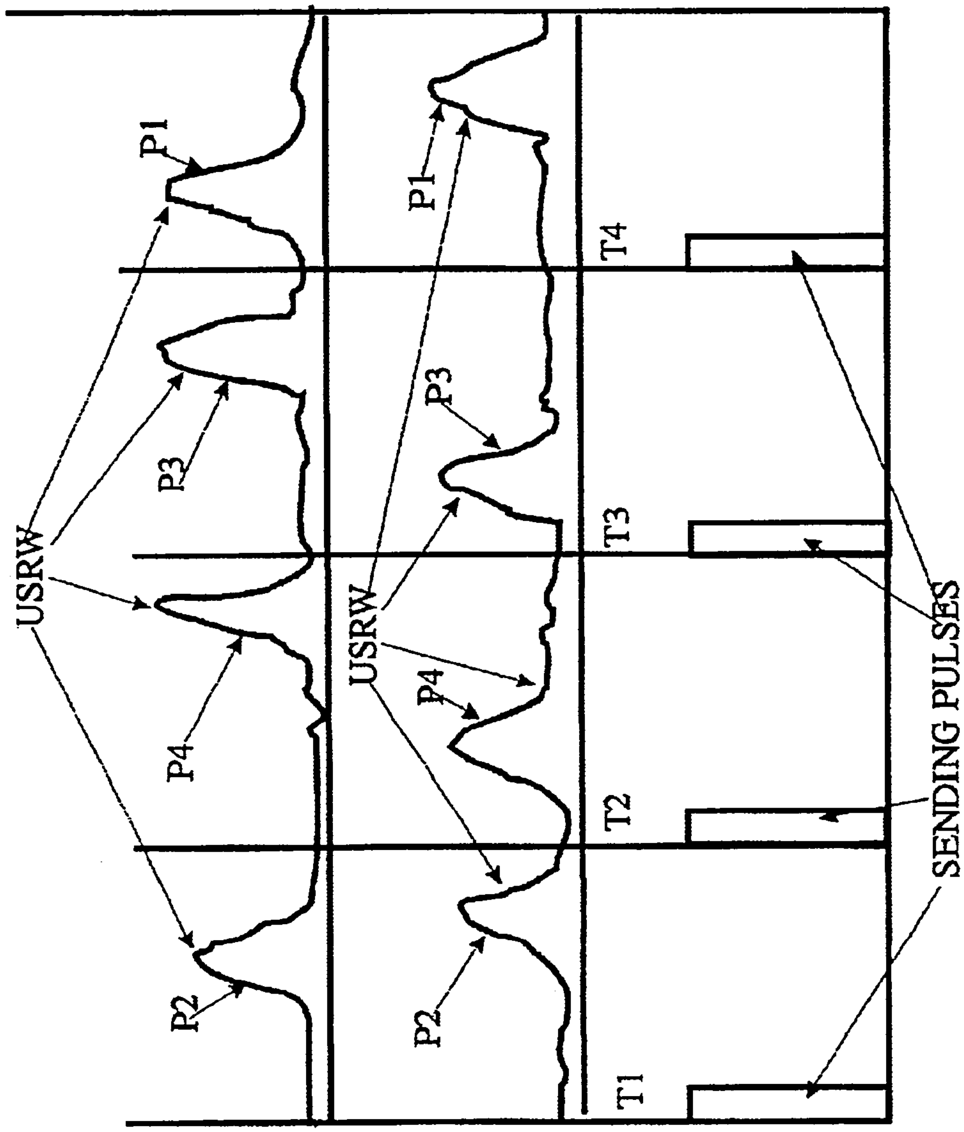


FIG. 4(a)

FIG. 4(b)

FIG. 4(c)

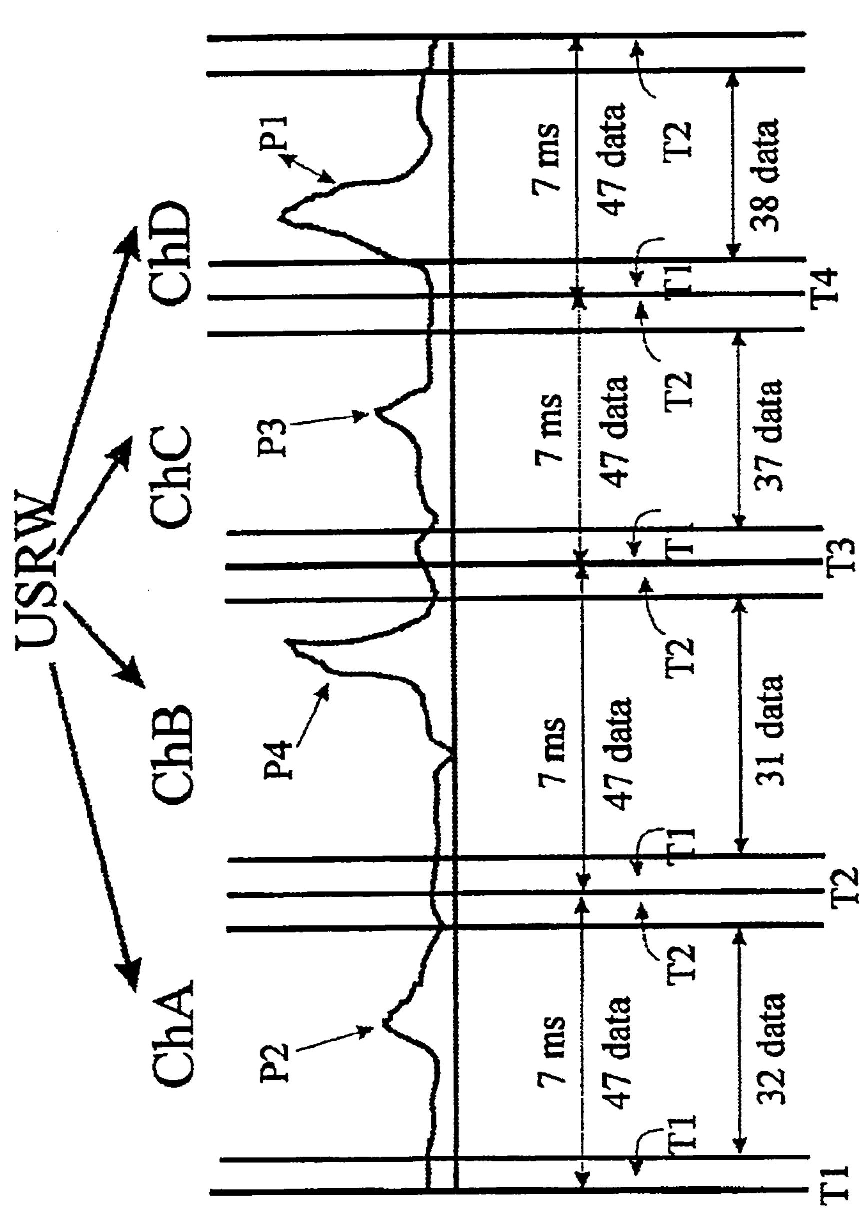

USRW
ChA
ChB
ChC
ChD
P1
P2
P3
P4
7 ms
7 ms
7 ms
7 ms
47 data
47 data
47 data
47 data
T1
T2
T1
T2
T1
T2
T1
T2
38 data
37 data
31 data
32 data
T1
T2
T3
T4

FIG. 5

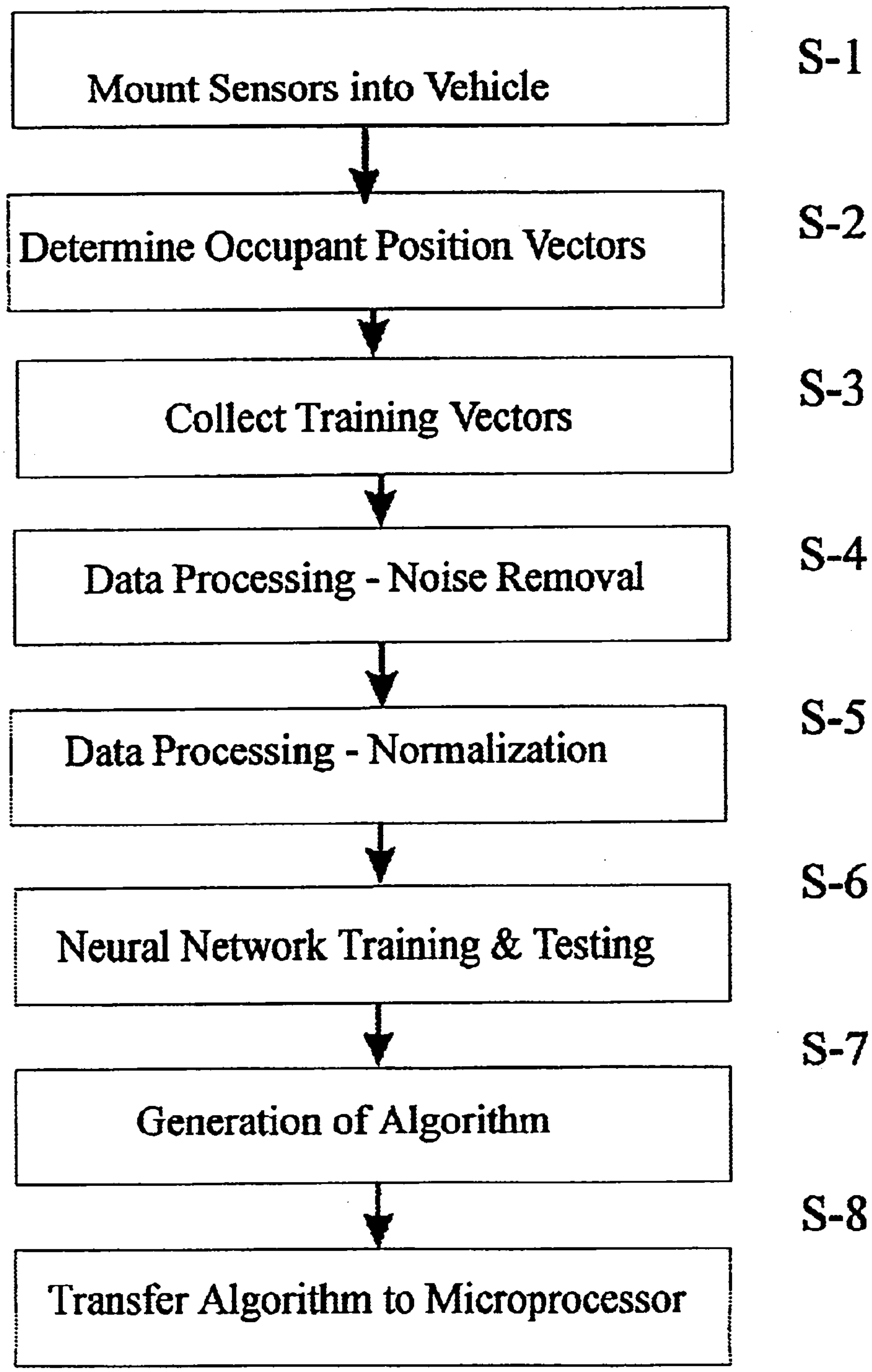

Mount Sensors into Vehicle
S-1
Determine Occupant Position Vectors
S-2
Collect Training Vectors
S-3
Data Processing - Noise Removal
S-4
Data Processing - Normalization
S-5
Neural Network Training & Testing
S-6
Generation of Algorithm
S-7
Transfer Algorithm to Microprocessor
S-8

FIG. 6

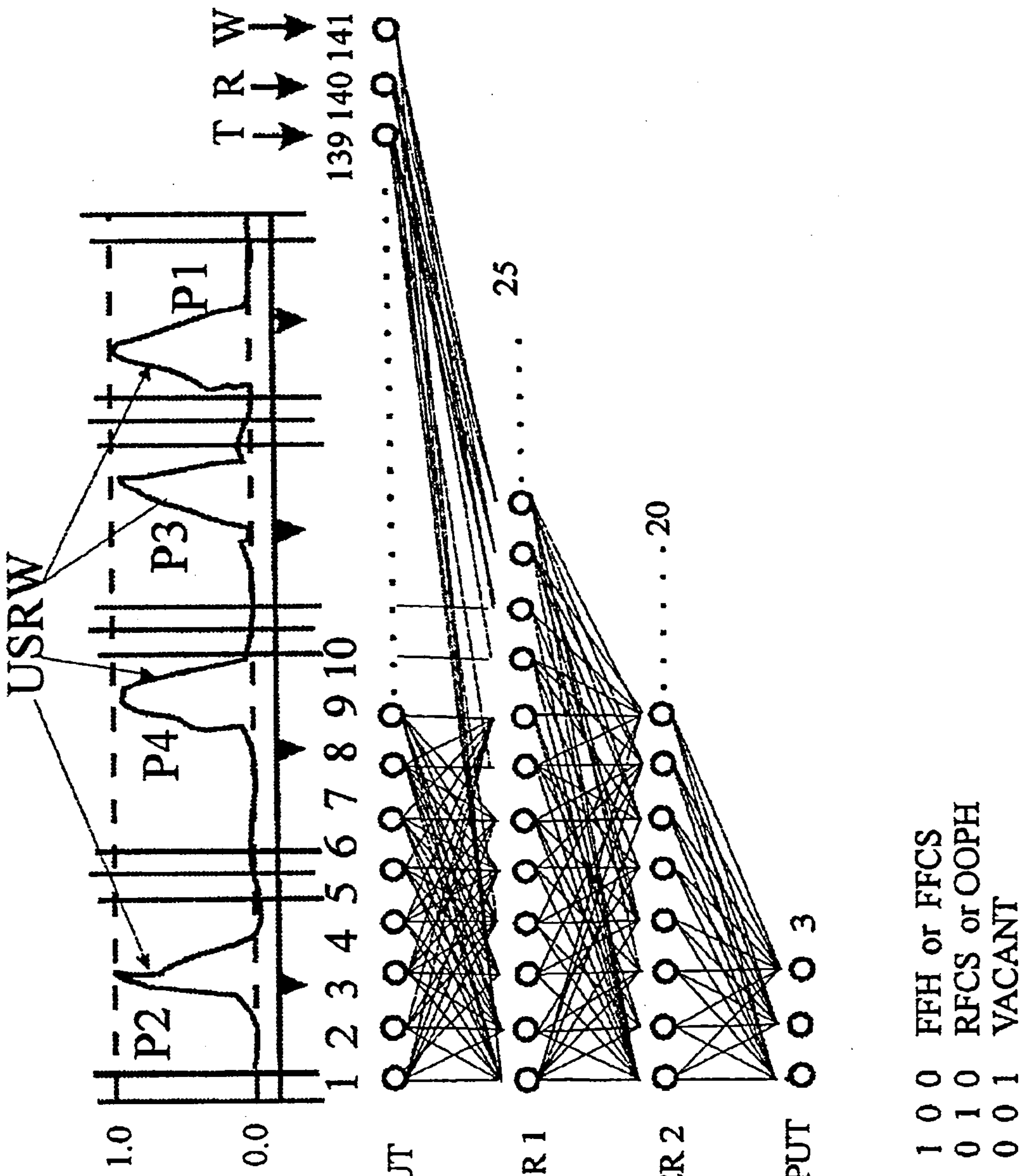

USRW
P1
P2
P3
P4
1.0
0.0
T R W
1 2 3 4 5 6 7 8 9 10
139 140 141
25
20
3
INPUT
LAYER 1
LAYER 2
OUTPUT
1 0 0 FFH or FFCS
0 1 0 RFCS or OOPH
0 0 1 VACANT

FIG. 7a

FIG. 7b

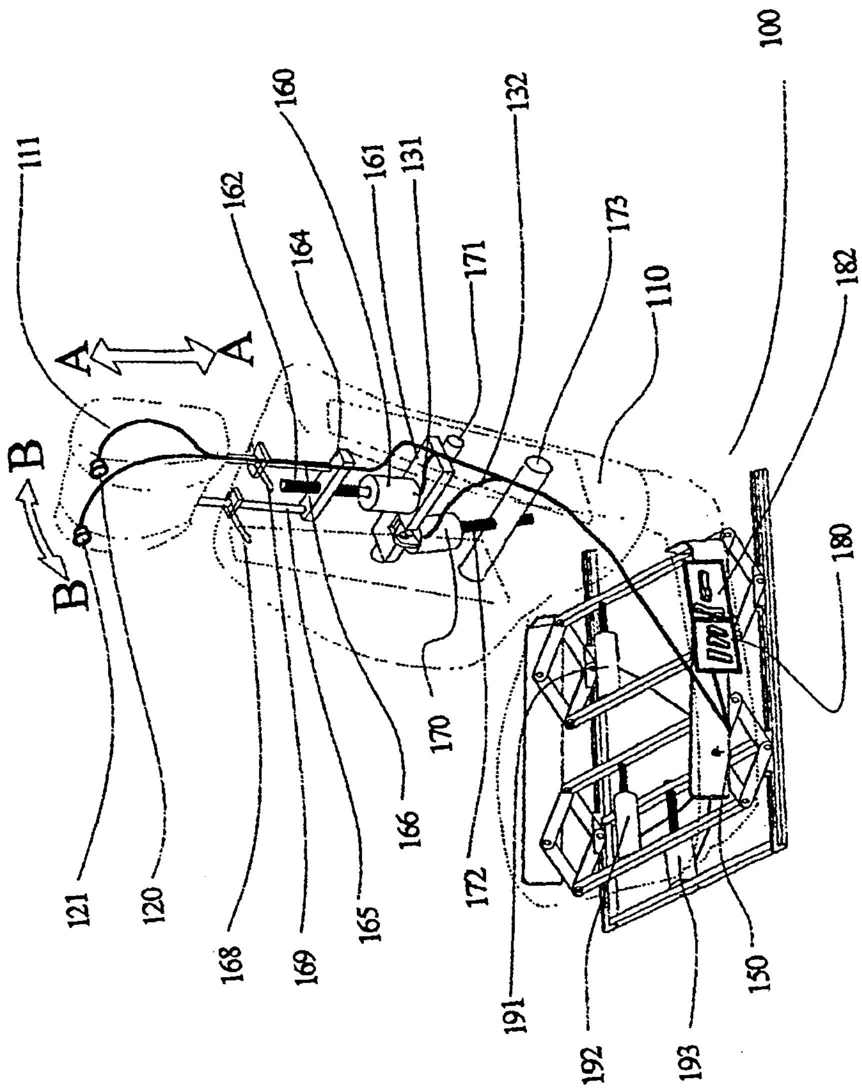

A
A
B
B
100
110
111
120
121
131
132
150
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FIG. 8

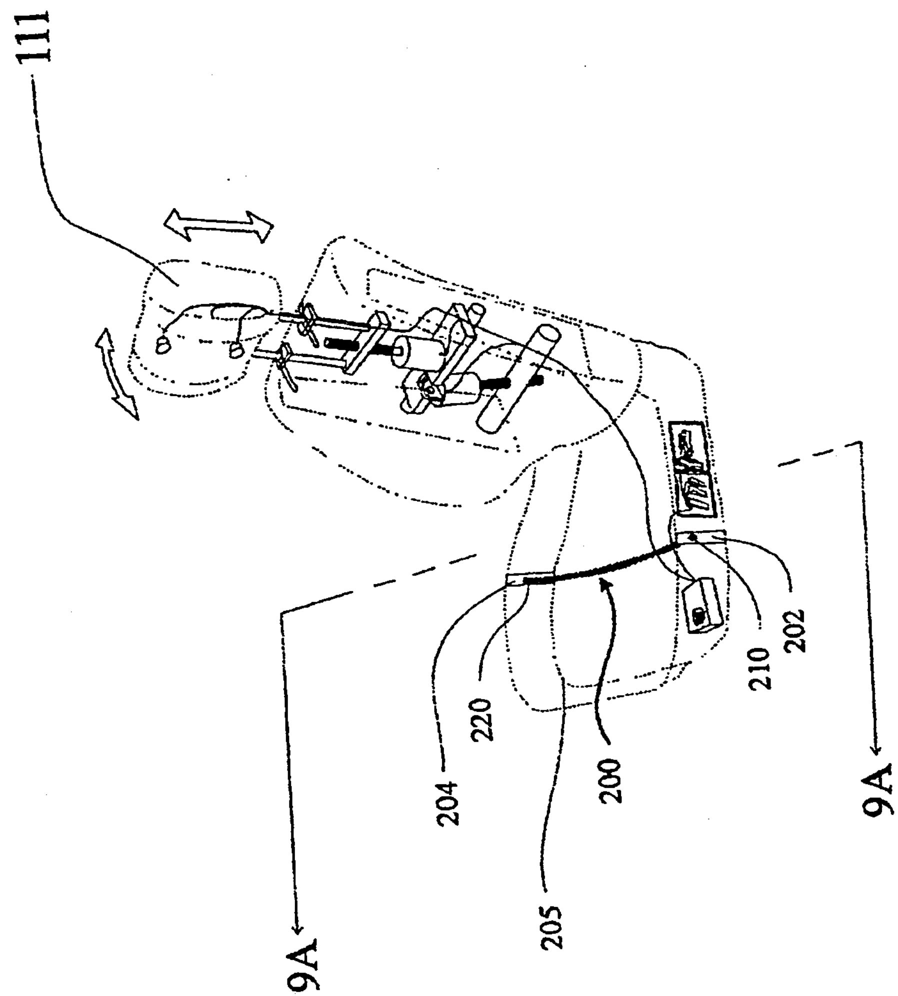


FIG. 9

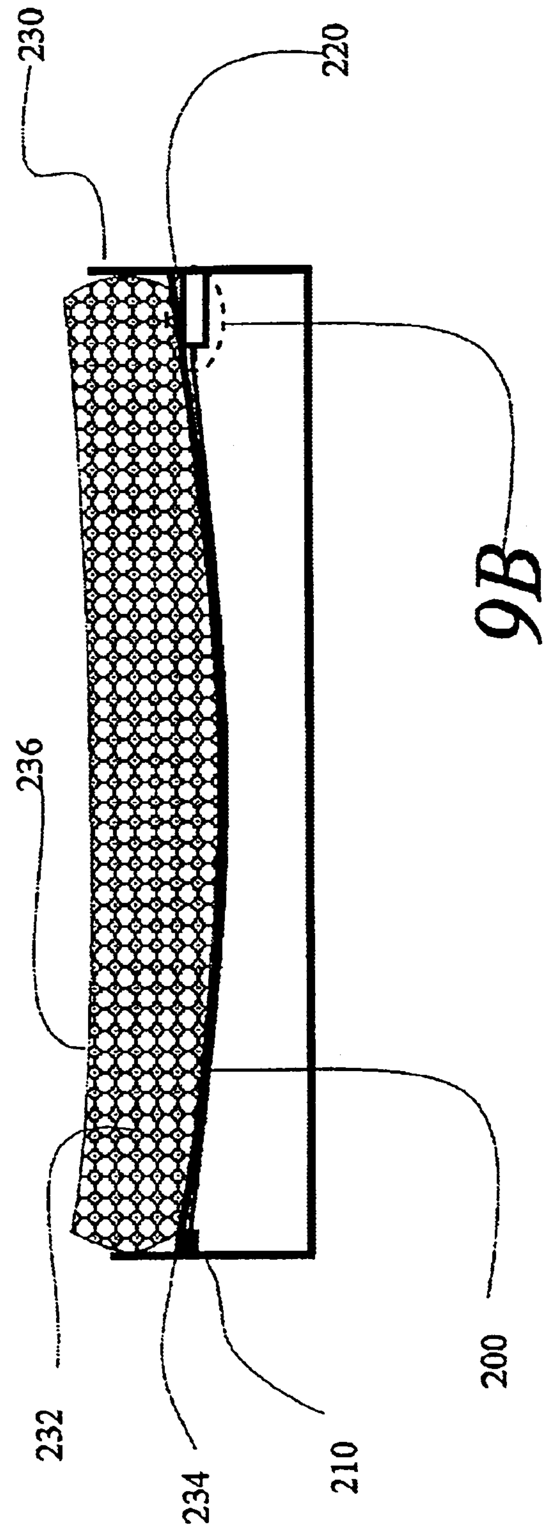


FIG. 9A

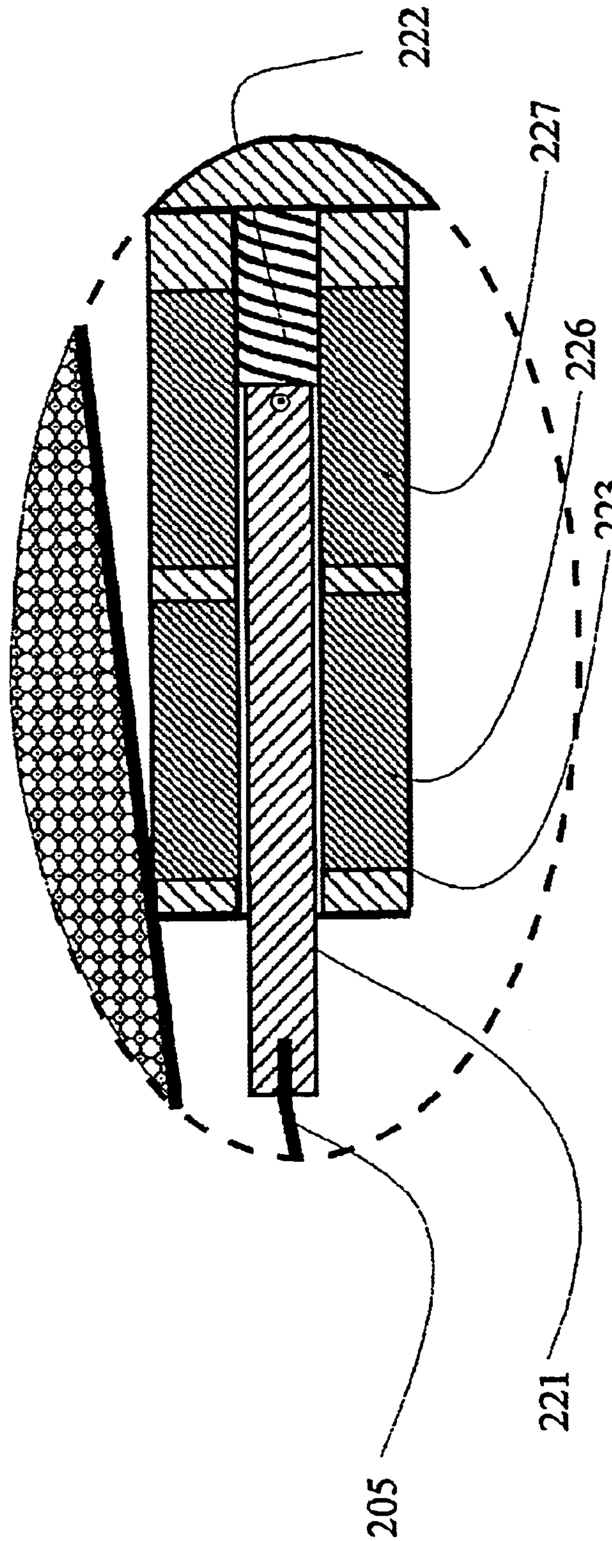


FIG. 9B

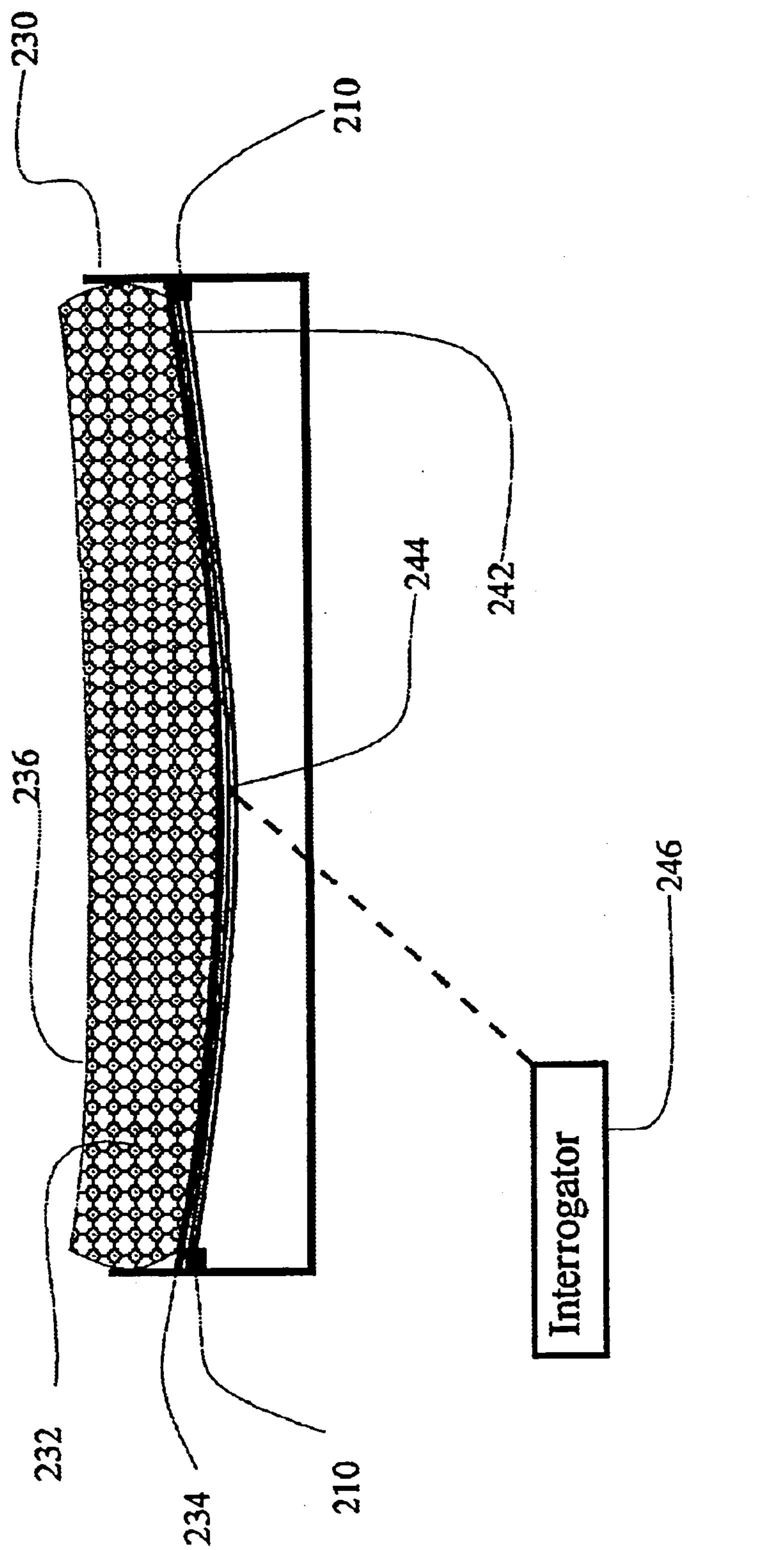


FIG. 9C

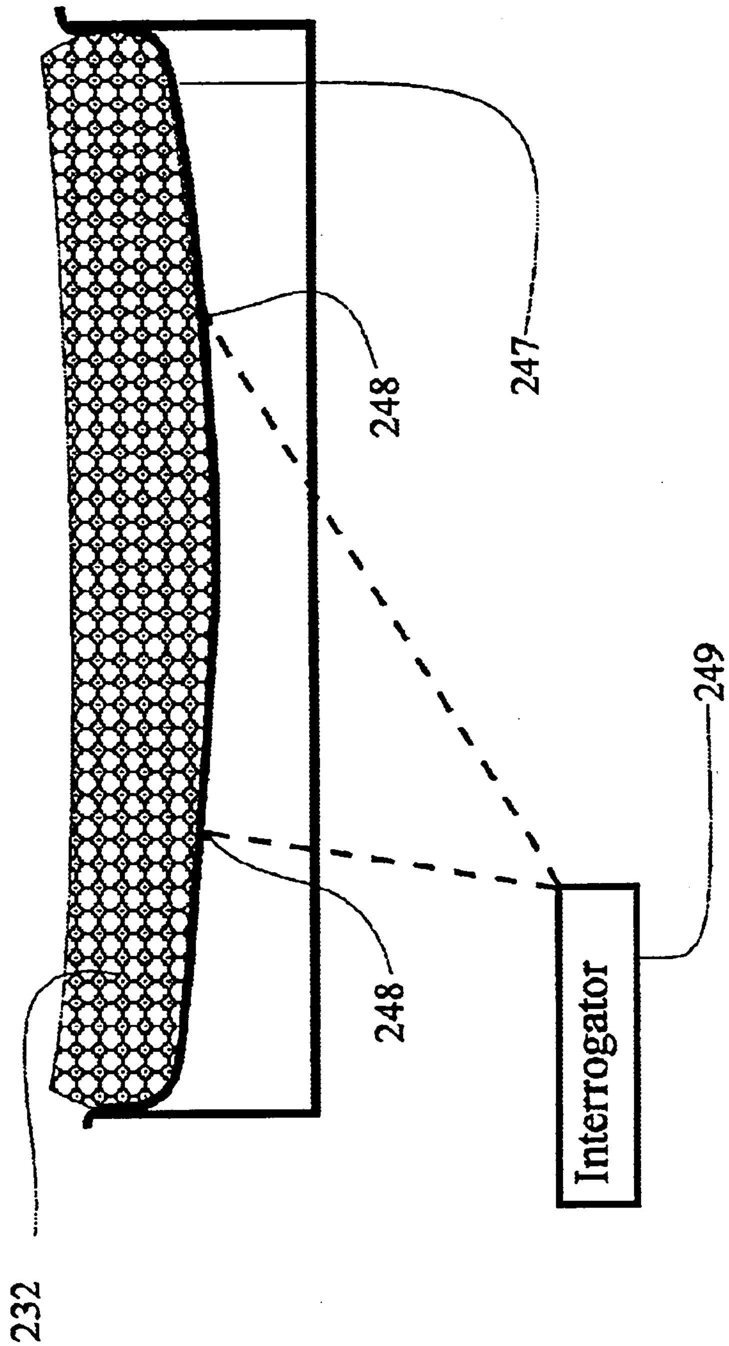


FIG. 9D

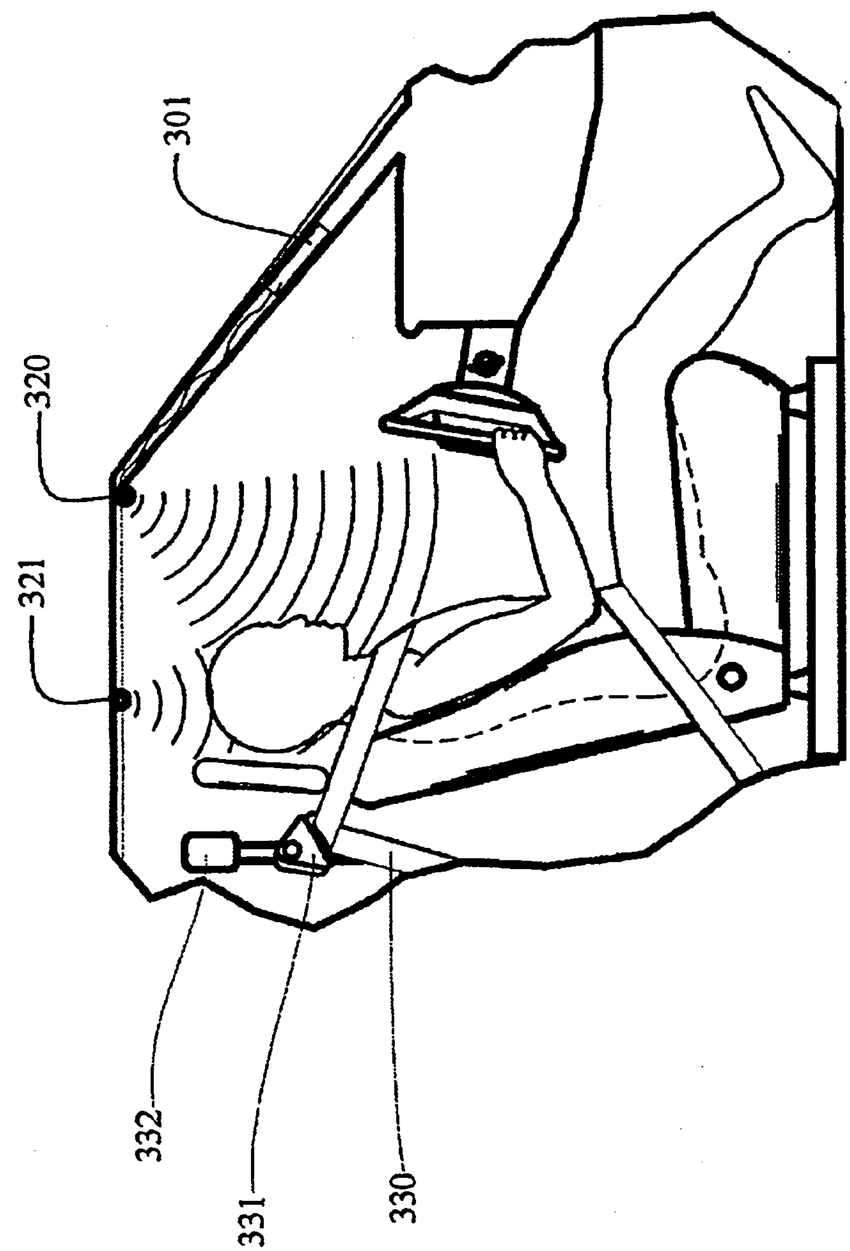


FIG. 10

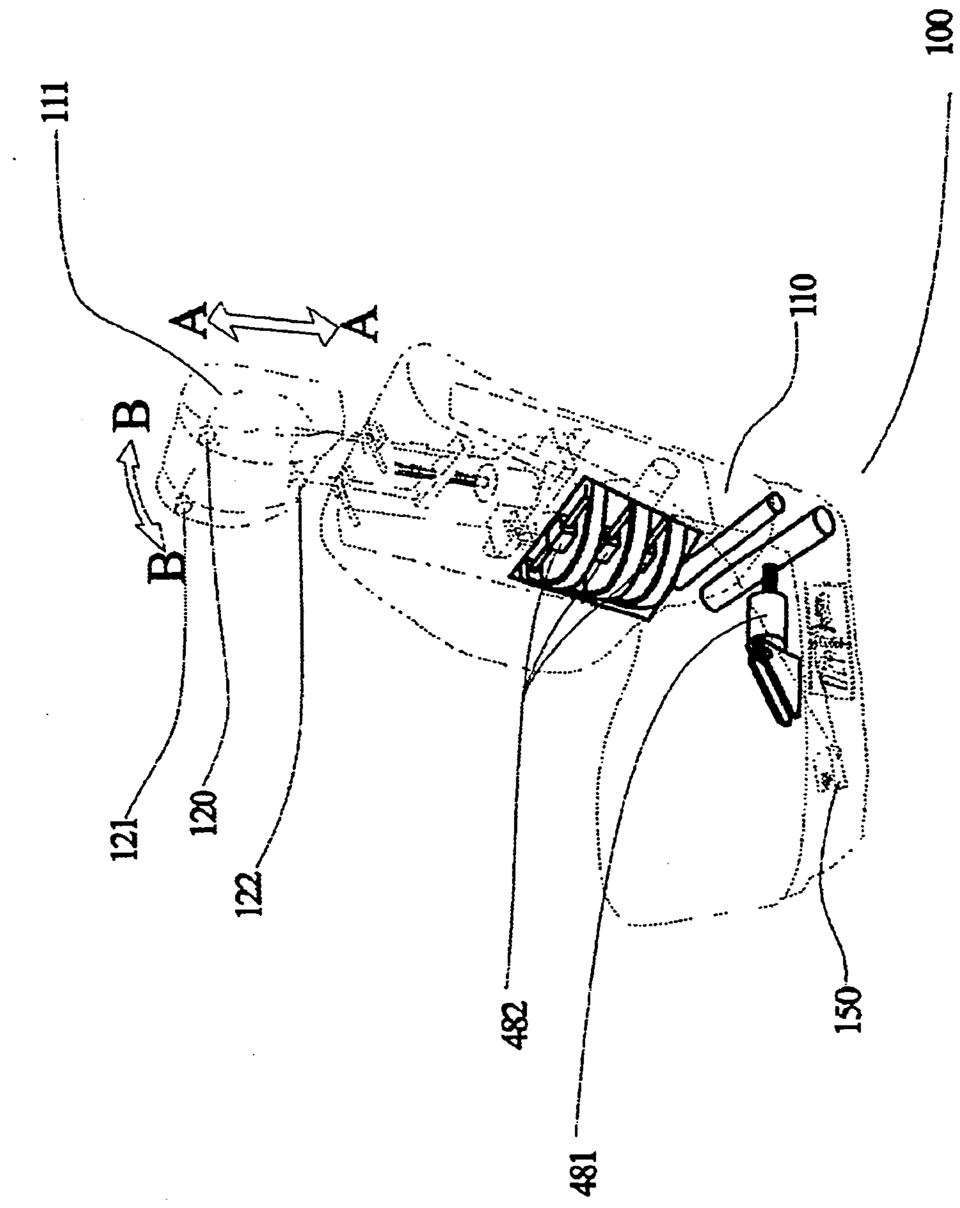


FIG. 11

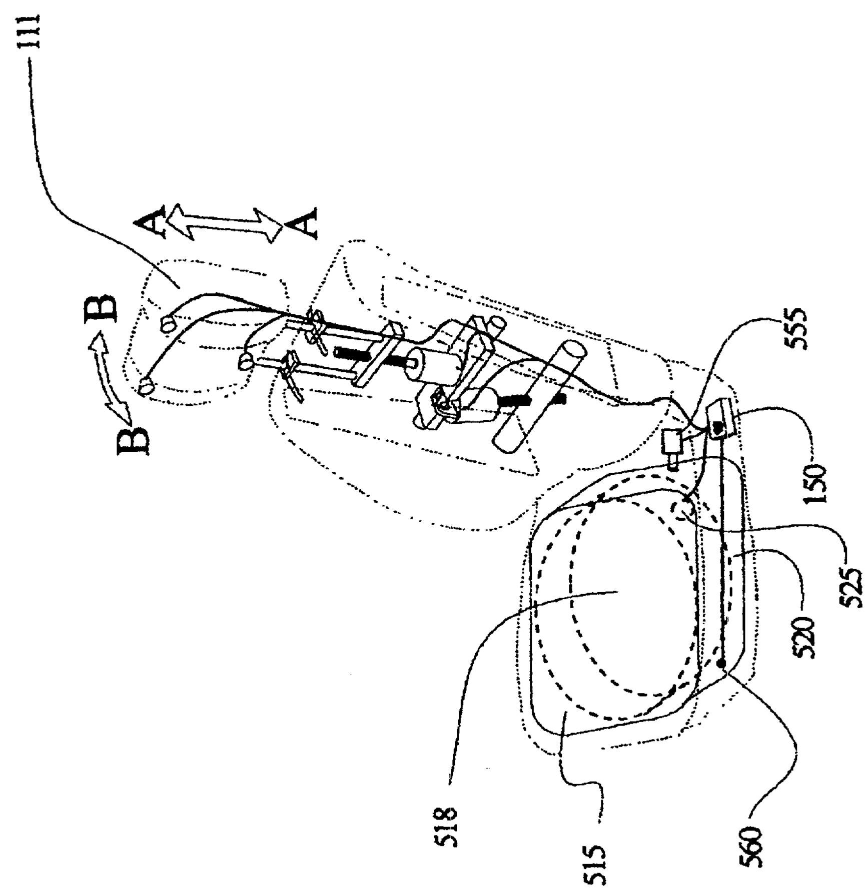


FIG. 12

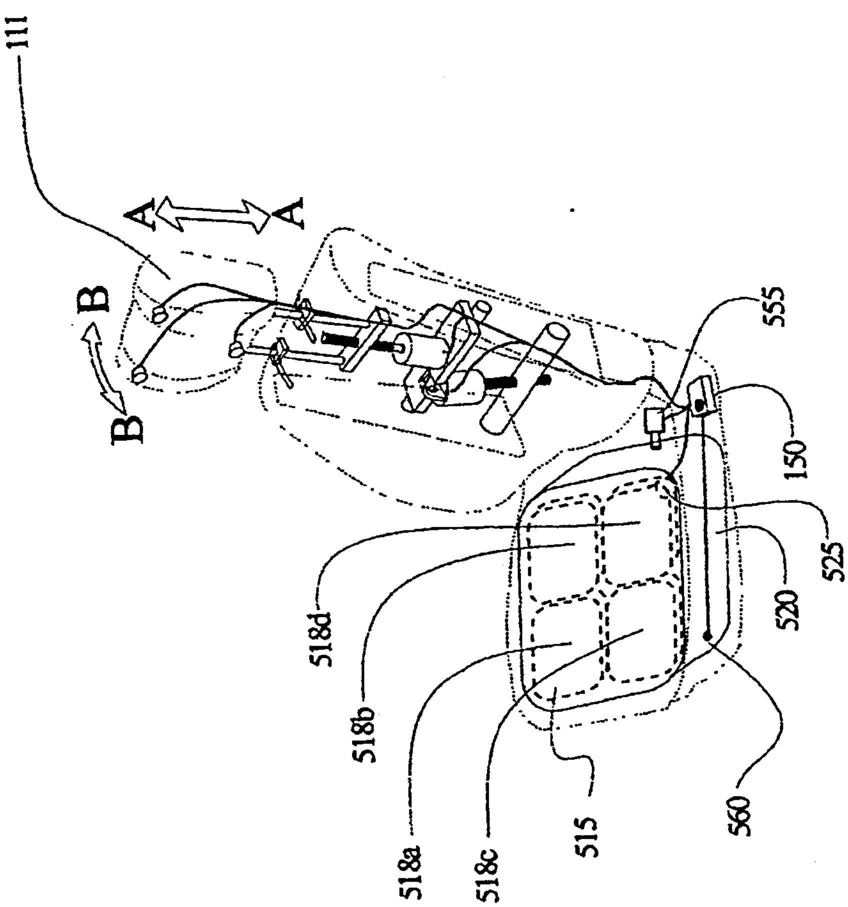


FIG. 12A

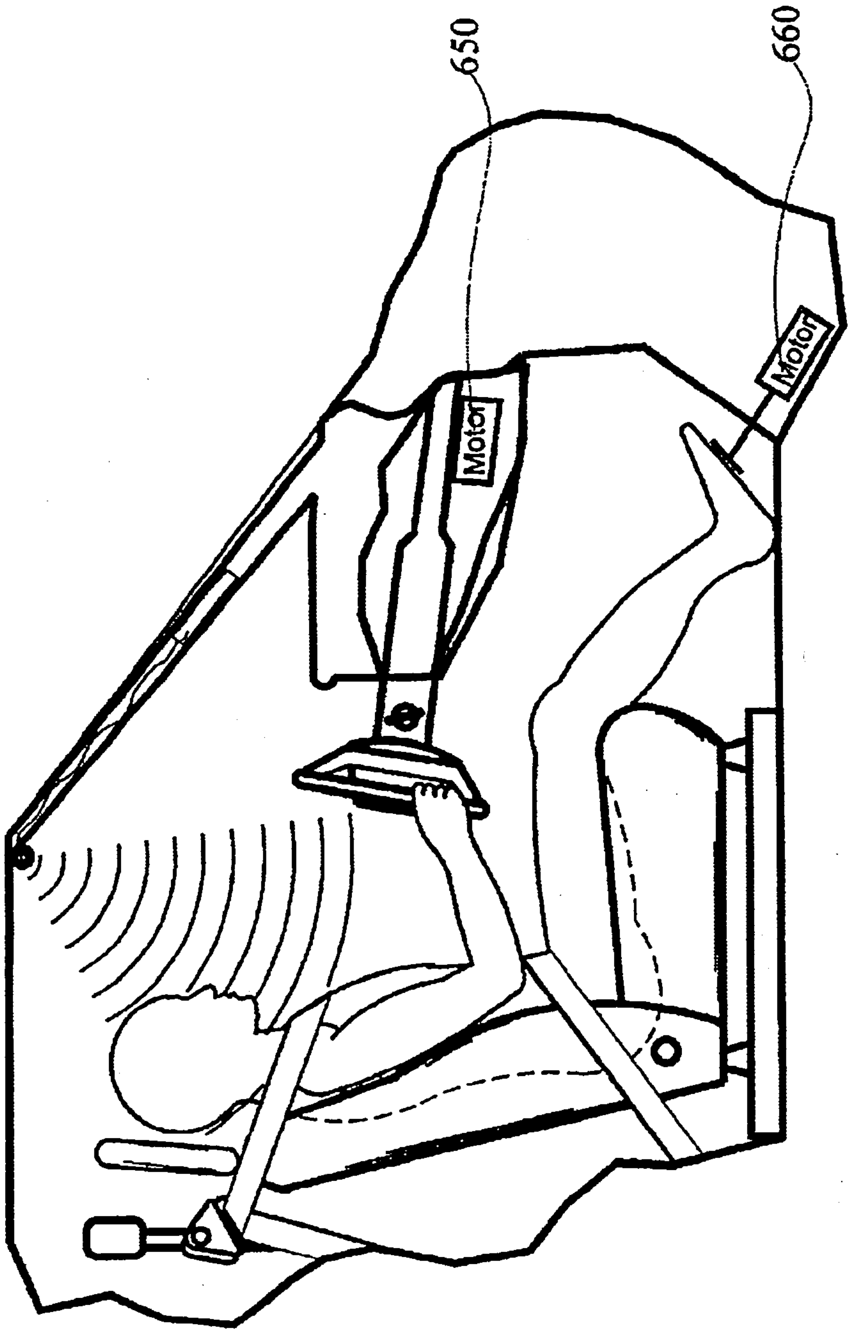


FIG. 13

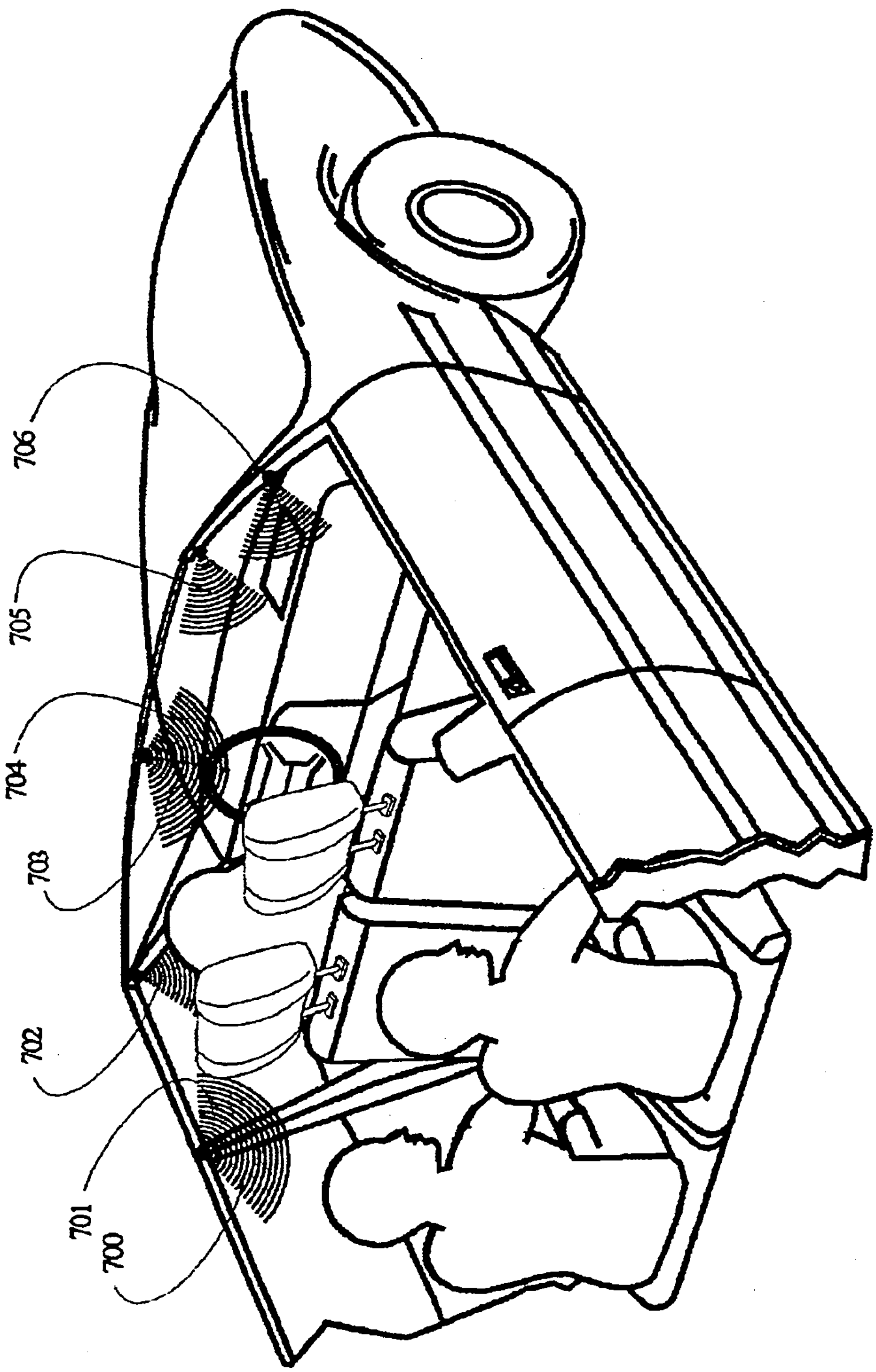


FIG. 14

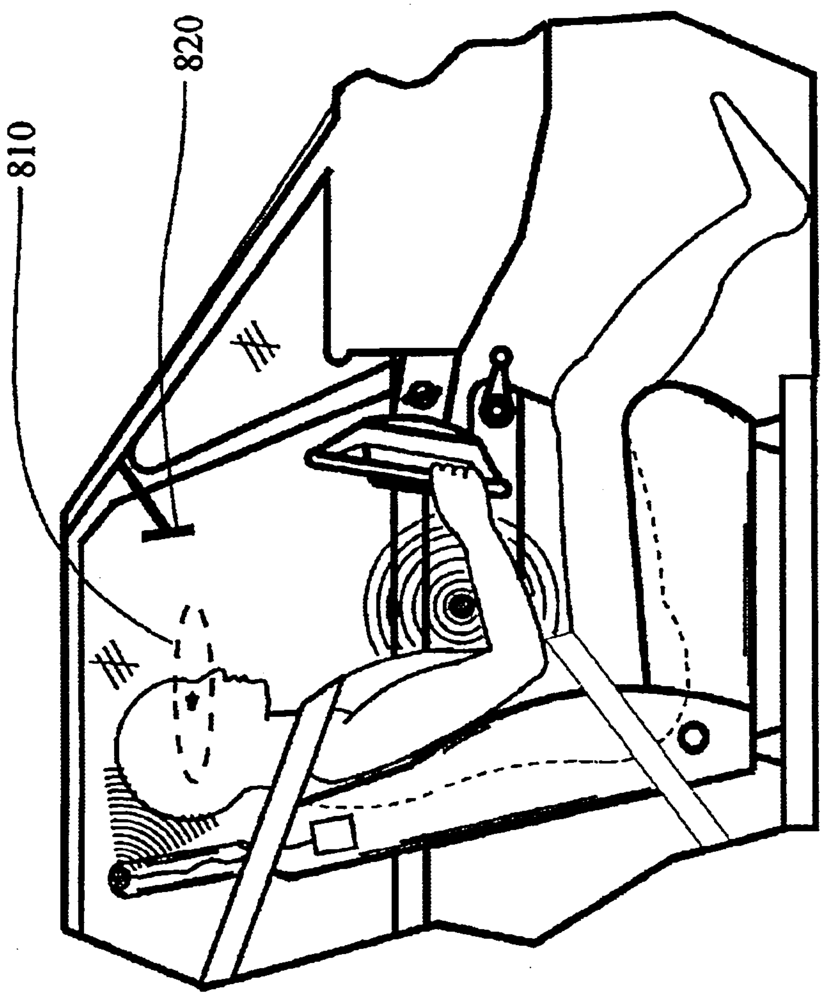


FIG. 15

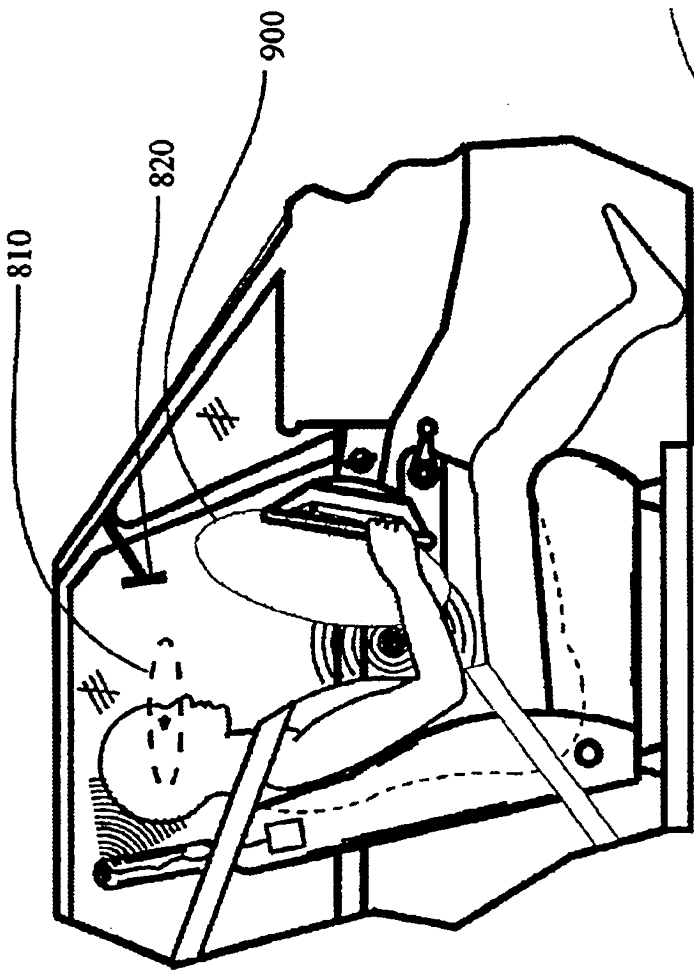


FIG. 16

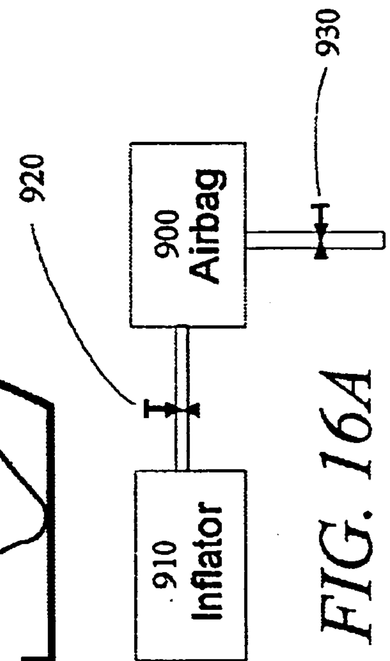


FIG. 16A

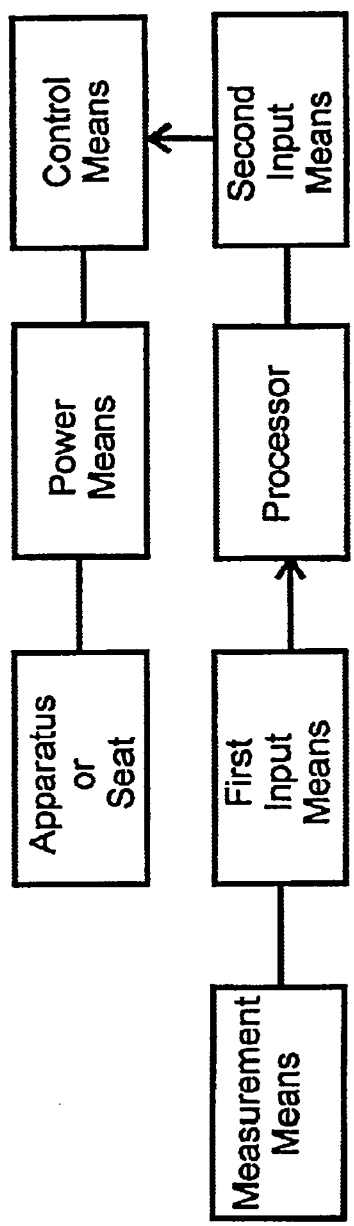


FIG. 17A

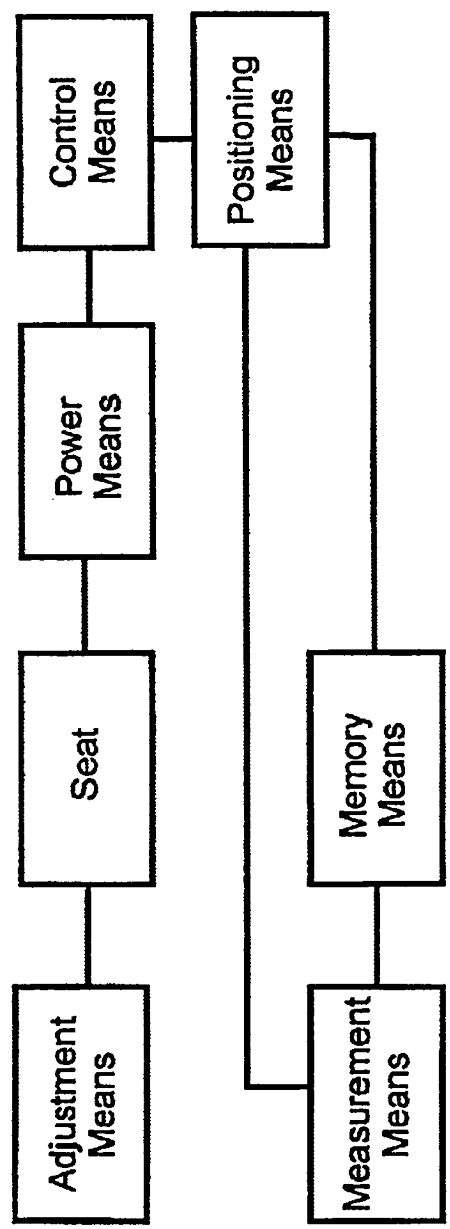
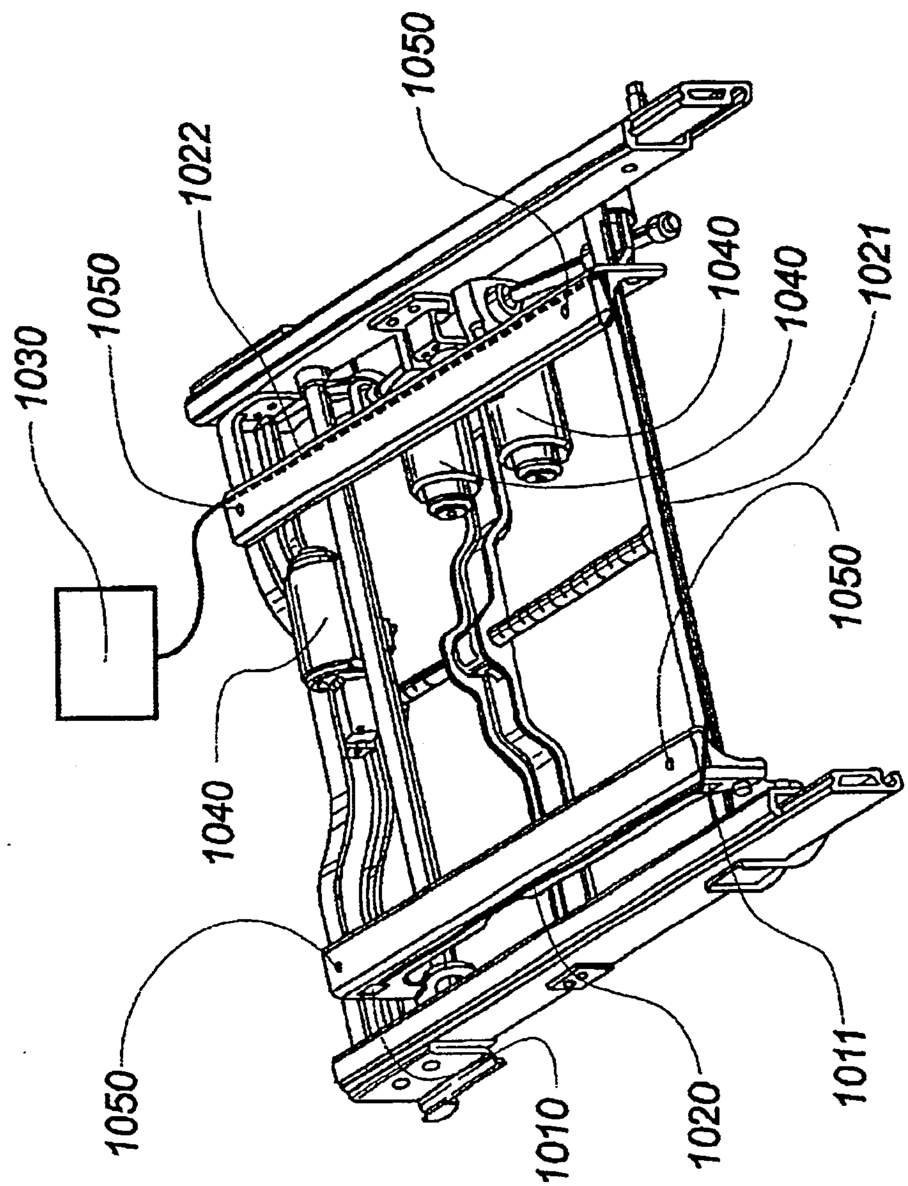


FIG. 17B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1021
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1050
1010
1020
1011

Fig. 18

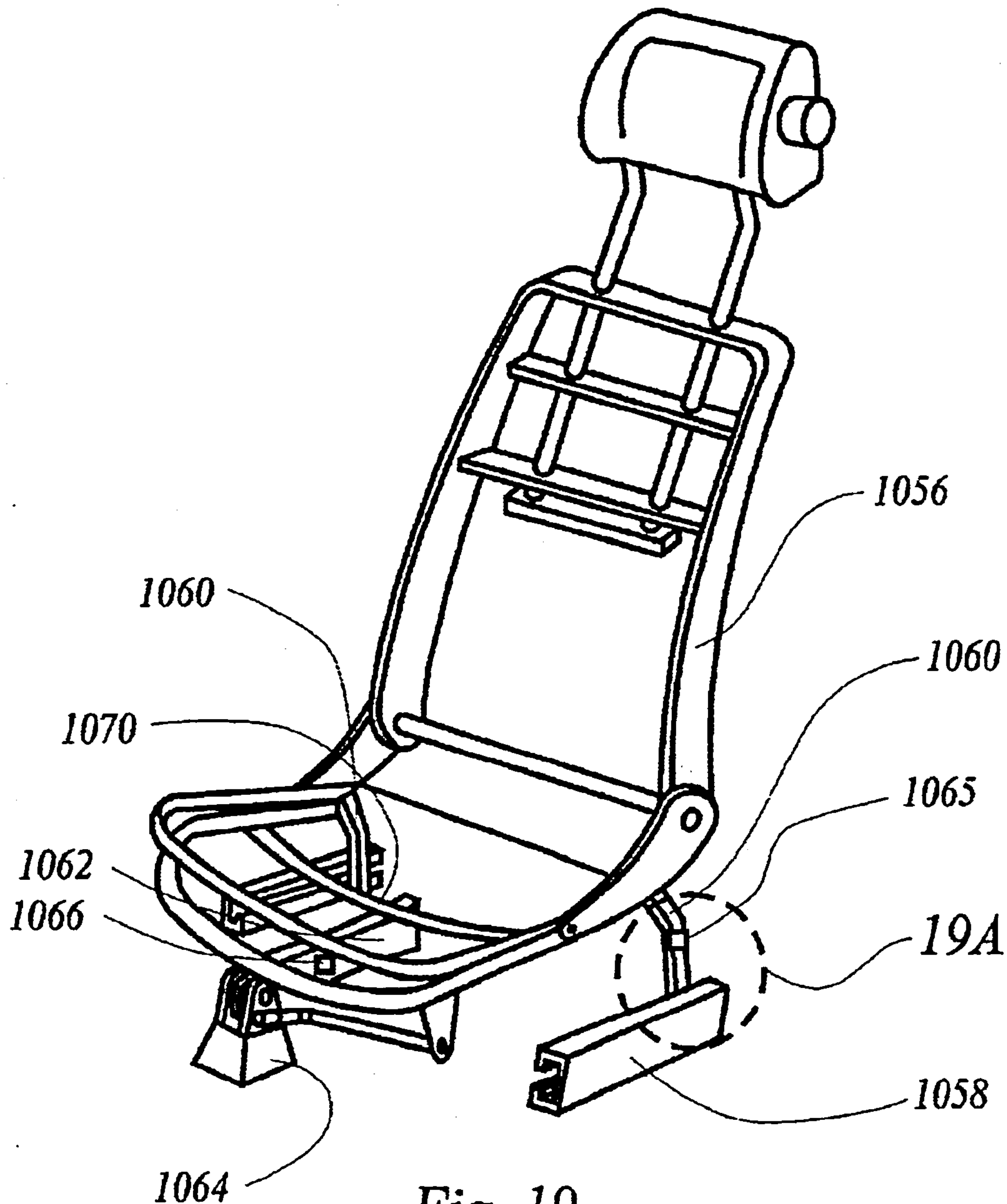

Fig. 19

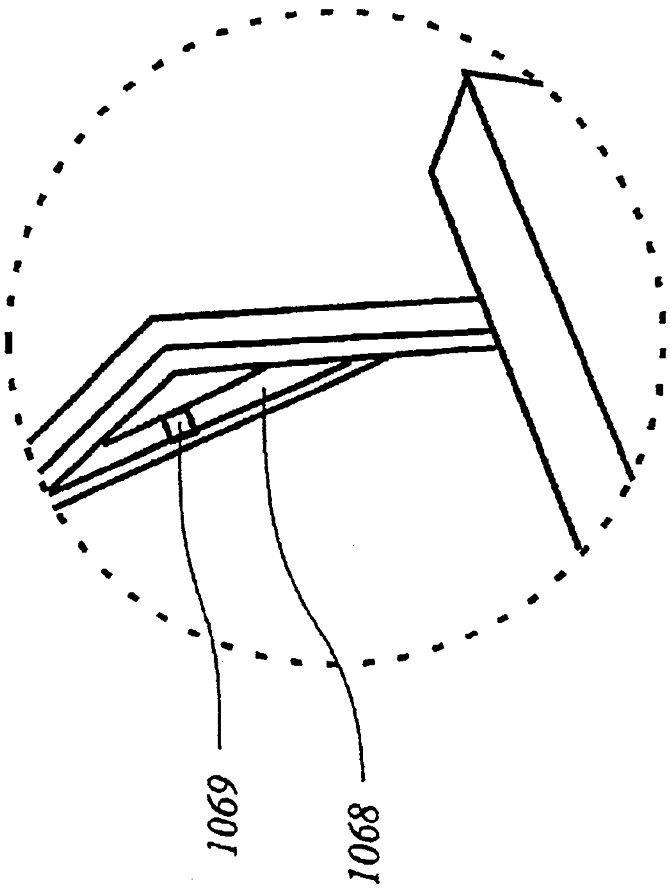

Fig. 19A

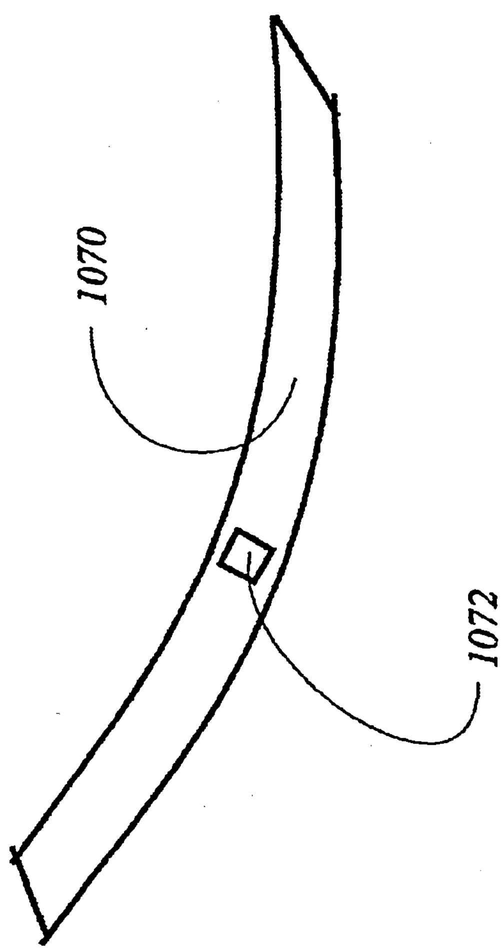

Fig. 19B

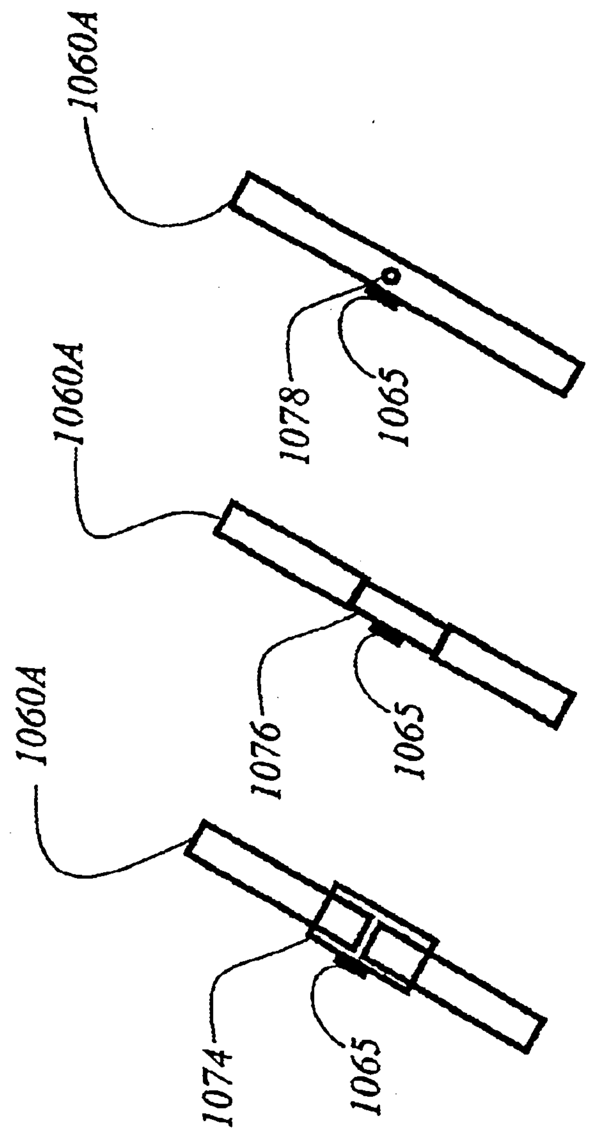

Fig. 20C

Fig. 20B

Fig. 20A

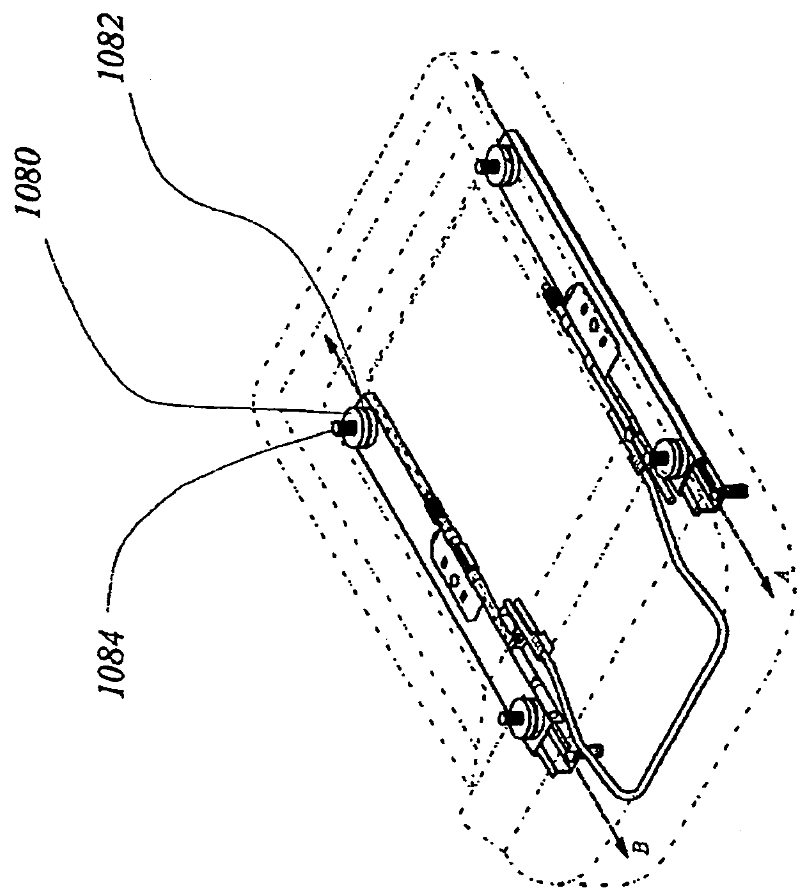

Fig. 21

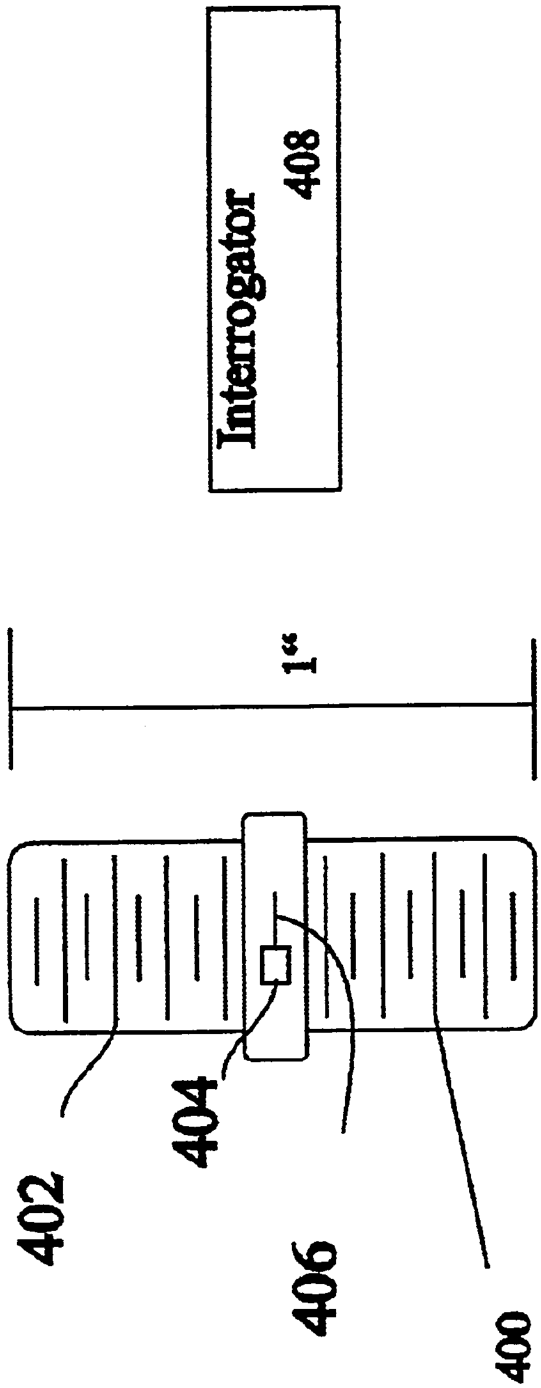

FIG. 21A

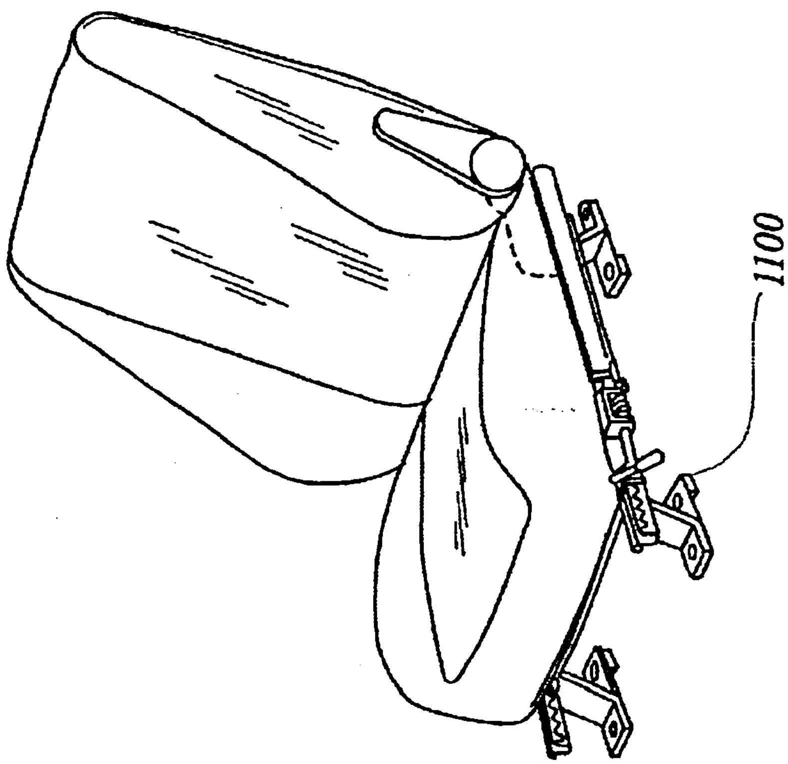

Fig. 22

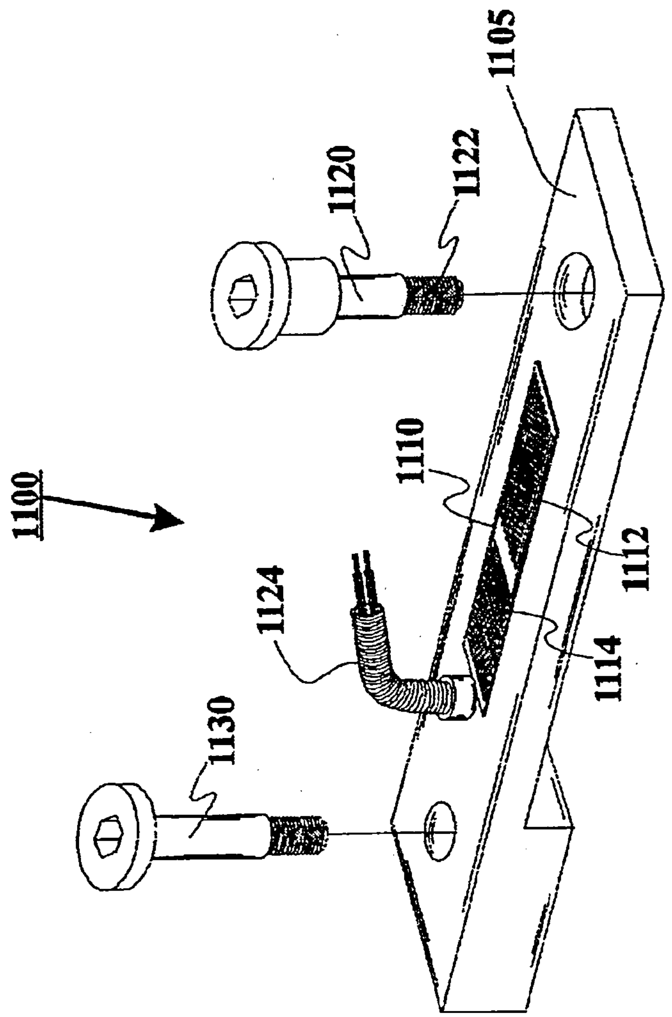

FIG. 22A

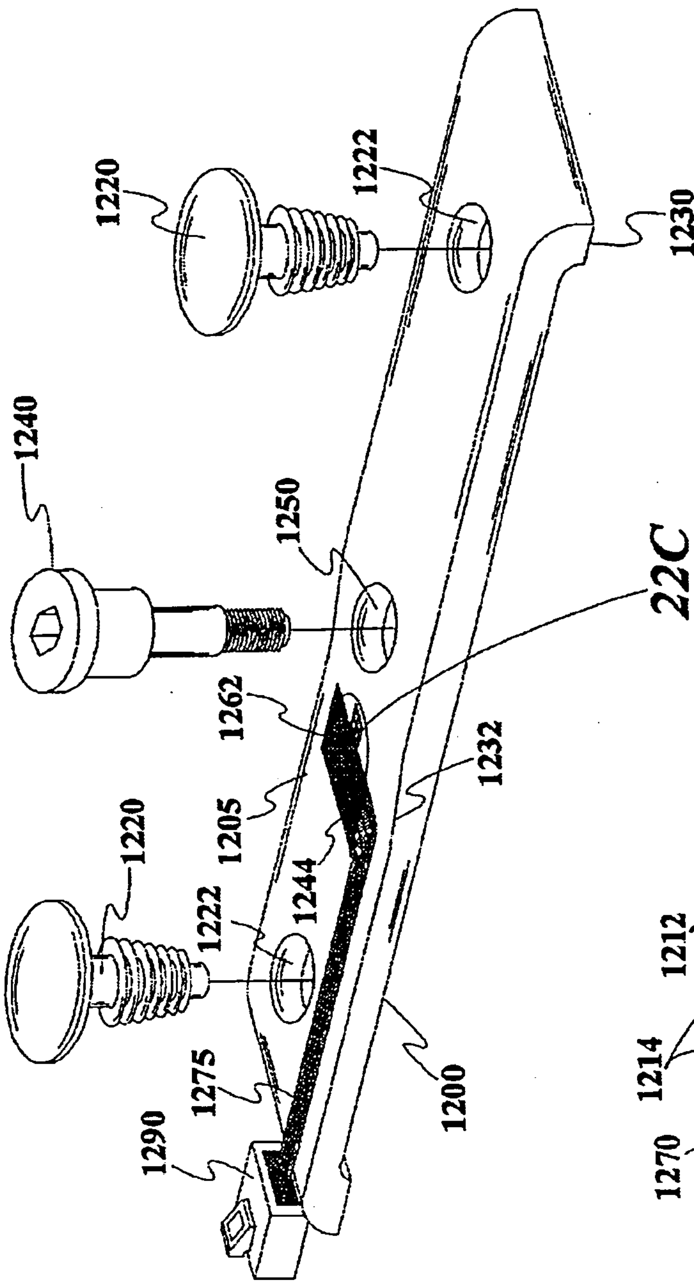

FIG. 22B

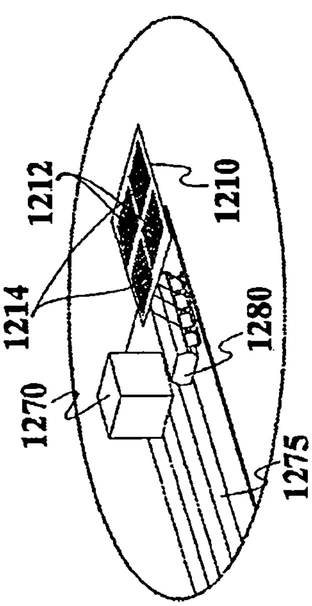

FIG. 22C

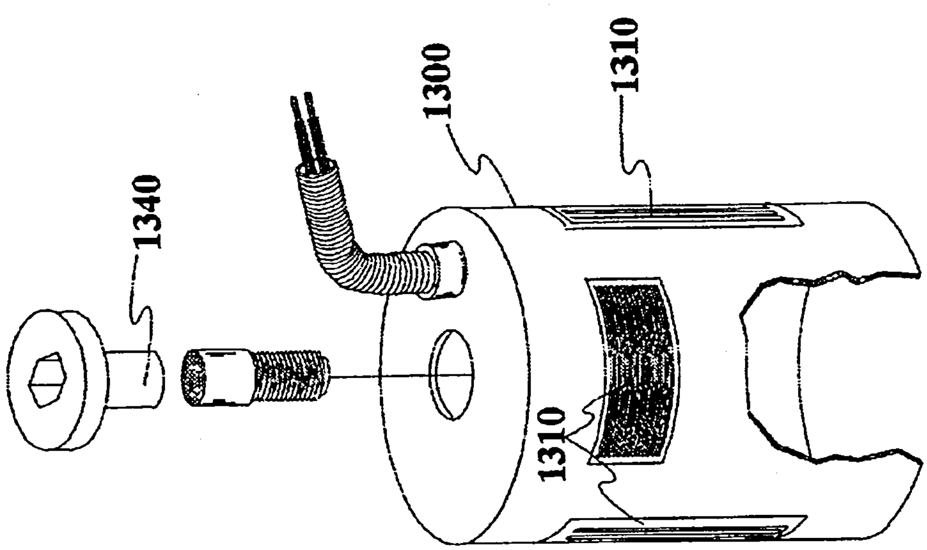

FIG. 22D

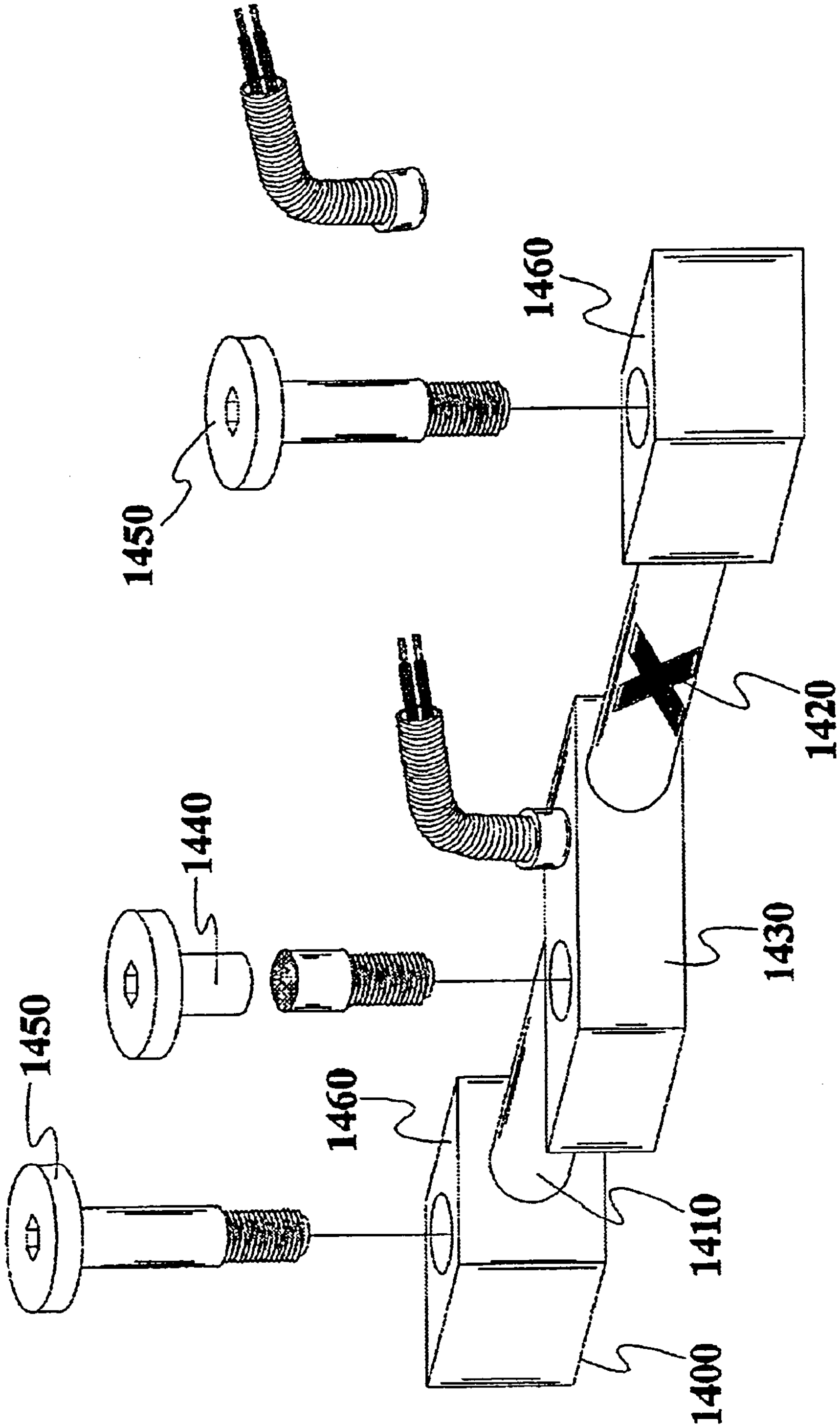

FIG. 22E

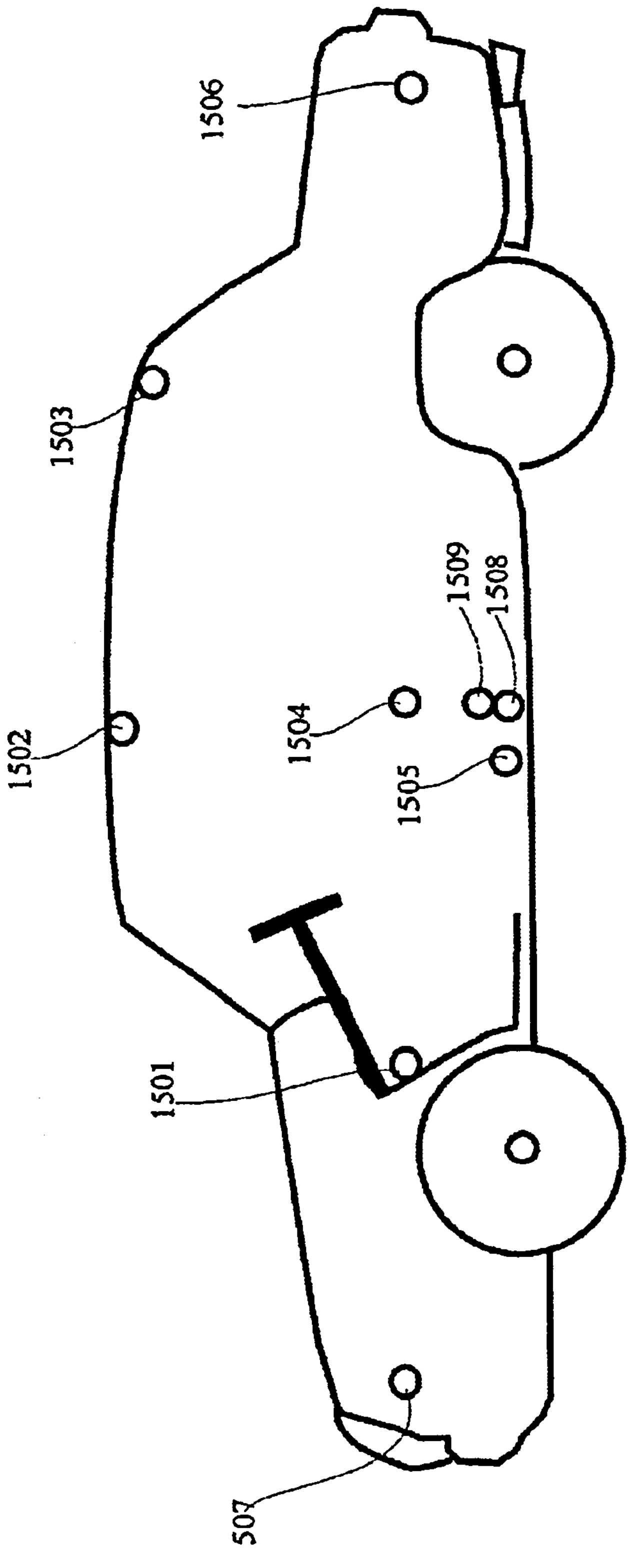

FIG. 23

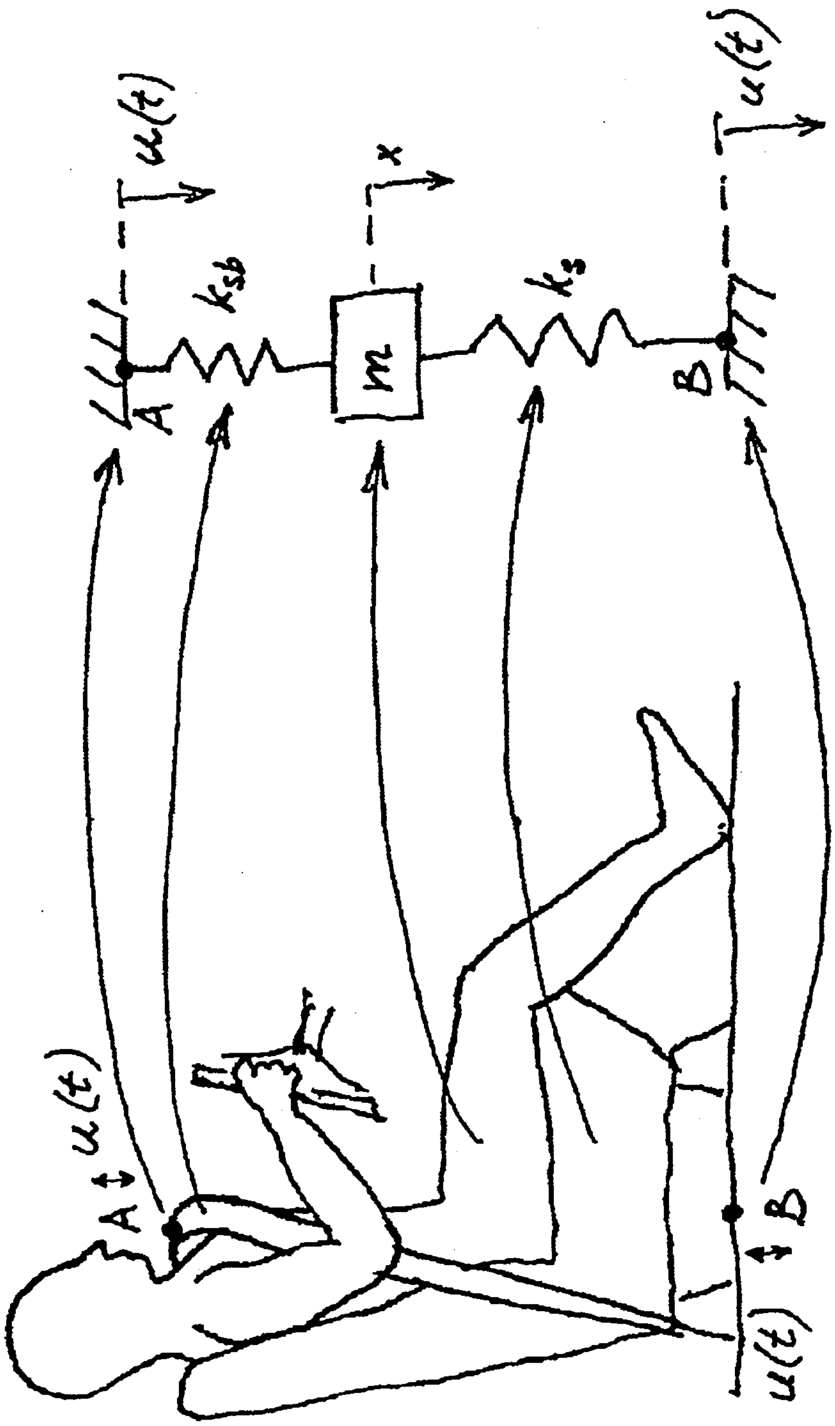

FIG. 24

APPARATUS AND METHOD FOR MEASURING WEIGHT OF AN OCCUPYING ITEM OF A SEAT

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of:

1) U.S. patent application Ser. No. 09/500,346 filed Feb. 8, 2000 which in turn is a continuation-in-part of U.S. patent application Ser. No. 09/128,490, filed Aug. 4, 1998, now U.S. Pat. No. 6,078,854, which in turn is a continuation-in-part of both U.S. patent application Ser. No. 08/474,783 filed Jun. 7, 1995, now U.S. Pat. No. 5,822,707, and U.S. patent application Ser. No. 08/970,822 filed Nov. 14, 1997, now U.S. Pat. No. 6,081,757;

2) U.S. patent application Ser. No. 09/849,558 filed May 4, 2001 now U.S. Pat. No. 6,653,577 which in turn is a continuation-in-part of U.S. patent application Ser. No. 09/193,209 filed Nov. 17, 1998, now U.S. Pat. No. 6,242, 701, which in turn is a continuation-in-part of U.S. patent application Ser. No. 09/128,490 filed Aug. 4, 1998, now U.S. Pat. No. 6,078,854, which in turn is a continuation-in-part of both U.S. patent application Ser. No. 08/474,783 filed Jun. 7, 1995, now U.S. Pat. No. 5,822,707, and U.S. patent application Ser. No. 08/970,822 filed Nov. 14, 1997, now U.S. Pat. No. 6,081,757;

3) U.S. patent application Ser. No. 09/849,559 filed May 4, 2001 which in turn is a continuation-in-part of U.S. patent application Ser. No. 09/193,209 filed Nov. 17, 1998, now U.S. Pat. No. 6,242,701, which in turn is a continuation-in-part of U.S. patent application Ser. No. 09/128,490 filed Aug. 4, 1998, now U.S. Pat. No. 6,078,854, which in turn is a continuation-in-part of both U.S. patent application Ser. No. 08/474,783 filed Jun. 7, 1995, now U.S. Pat. No. 5,822,707, and U.S. patent application Ser. No.08/970,822 filed Nov. 14, 1997, now U.S. Pat. No. 6,081,757;

4) U.S. patent application Ser. No. 09/901,879 filed Jul. 9, 2001 which in turn is a continuation of U.S. patent application Ser. No. 09/849,559 filed May 4, 2001 which in turn is a continuation-in-part of U.S. patent application Ser. No.09/193,209 filed Nov. 17, 1998, now U.S. Pat. No. 6,242,701, which in turn is a continuation-in-part of U.S. patent application Ser. No. 09/128,490 filed Aug. 4, 1998, now U.S. Pat. No. 6,078,854, which in turn is a continuation-in-part of both U.S. patent application Ser. No. 08/474,783 filed Jun. 7, 1995, now U.S. Pat. No. 5,822,707, and U.S. patent application Ser. No. 08/970,822 filed Nov. 14, 1997, now U.S. Pat. No. 6,081,757;

5) U.S. patent application Ser. No.09/753,186 filed Jan. 2, 2001; now U.S. Pat. No. 6,484,080

6) U.S. patent application Ser. No. 09/767,020 filed Jan. 23, 2001 now U.S. Pat. No. 6,533,316; and

7) U.S. patent application Ser. No. 09/770,974 filed Jan. 26, 2001 now U.S. Pat. No. 6,648,367.

FIELD OF THE INVENTION

The present invention relates to methods and apparatus for measuring the weight of an occupying item of a seat, in particular, a seat in an automotive vehicle.

The present invention also relates to apparatus and methods for adjusting a vehicle component, system or subsystem in which the occupancy of a seat, also referred to as the "seated state" herein, is evaluated using at least a weight measuring apparatus and the component, system or subsystem may then be adjusted based on the evaluated occupancy thereof. The vehicle component, system or subsystem, hereinafter referred to simply as a component, may be any adjustable component of the vehicle including, but not limited to, the bottom portion and backrest of the seat, the rear view and side mirrors, the brake, clutch and accelerator pedals, the steering wheel, the steering column, a seat armrest, a cup holder, the mounting unit for a cellular telephone or another communications or computing device and the visors. Further, the component may be a system such an as airbag system, the deployment or suppression of which is controlled based on the seated-state of the seat. The component may also be an adjustable portion of a system the operation of which might be advantageously adjusted based on the seated-state of the seat, such as a device for regulating the inflation or deflation of an airbag that is associated with an airbag system.

The present invention also relates to apparatus and method for automatically adjusting a vehicle component to a selected or optimum position for an occupant of a seat based on at least two measured morphological characteristics of the occupant, one of which is the weight of the occupant. Other morphological characteristics include the height of the occupant, the length of the occupant's arms, the length of the occupant's legs, the occupant's head diameter, facial features and the inclination of the occupant's back relative to the seat bottom. Other morphological characteristics are also envisioned for use in the invention including iris pattern properties from an iris scan, voice print and finger and hand prints.

BACKGROUND OF THE INVENTION

Automobiles equipped with airbags are well known in the prior art. In such airbag systems, the car crash is sensed and the airbags rapidly inflated thereby insuring the safety of an occupation in a car crash. Many lives have now been saved by such airbag systems. However, depending on the seated state of an occupant, there are cases where his or her life cannot be saved even by present airbag systems. For example, when a passenger is seated on the front passenger seat in a position other than a forward facing, normal state, e.g., when the passenger is out of position and near the deployment door of the airbag, there will be cases when the occupant will be seriously injured or even killed by the deployment of the airbag.

Also, sometimes a child seat is placed on the passenger seat in a rear facing position and there are cases where a child sitting in such a seat has been seriously injured or killed by the deployment of the airbag.

Furthermore, in the case of a vacant seat, there is no need to deploy an airbag, and in such a case, deploying the airbag is undesirable due to a high replacement cost and possible release of toxic gases into the passenger compartment. Nevertheless, most airbag systems will deploy the airbag in a vehicle crash even if the seat is unoccupied.

For these reasons, there has been proposed a seated-state detecting unit such as disclosed in the following U.S. patents, which are incorporated herein by reference in their entirety to the extent the disclosure of these patents is necessary, assigned to the current assignee of the present application: Breed et al. (U.S. Pat. No. 5,563,462); Breed et al. (U.S. Pat. No. 5,829,782); Breed et al. (U.S. Pat. No. 5,822,707): Breed et al. (U.S. Pat. No. 5,694,320); Breed et al. (U.S. Pat. No. 5,748,473); and Varga et al. (U.S. Pat. No. 5,943,295). Typically, in some of these designs as many as three or four sensors or sets of sensors are installed at three or four points in a vehicle passenger compartment for

transmitting ultrasonic or electromagnetic waves toward the passenger or driver's seat and receiving the reflected waves. Using appropriate hardware and software, the approximate configuration of the occupancy of either the passenger or driver seat can be determined thereby identifying and categorizing the occupancy of the relevant seat.

However, in the aforementioned literature using ultrasonics, the pattern of reflected ultrasonic waves from an adult occupant who may be out of position is sometimes similar to the pattern of reflected waves from a rear facing child seat. Also, it is sometimes difficult to discriminate the wave pattern of a normally seated child with the seat in a rear facing position from an empty seat with the seat in a more forward position. In other cases, the reflected wave pattern from a thin slouching adult with raised knees can be similar to that from a rear facing child seat. In still other cases, the reflected pattern from a passenger seat which is in a forward position can be similar to the reflected wave pattern from a seat containing a forward facing child seat or a child sitting on the passenger seat. In each of these cases, the prior art ultrasonic systems can suppress the deployment of an airbag when deployment is desired or, alternately, can enable deployment when deployment is not desired. Similar confusing situations can occur also for capacitive, electric field and optical occupant sensing systems.

If the discrimination between these cases can be improved, then the reliability of the seated-state detecting unit can be improved and more people saved from death or serious injury, In addition, the unnecessary deployment of an airbag can be prevented.

With respect to the adjustment of a vehicular seat, the adjustment of an automobile seat occupied by a driver of the vehicle is now accomplished by the use of either electrical switches and motors or by mechanical levers. As a result, the driver's seat is rarely placed at the proper driving position which is defined as the seat location which places the eyes of the driver in the so-called "eye ellipse" and permits him or her to comfortably reach the pedals and steering wheel. The "eye ellipse" is the optimum eye position relative to the windshield and rear view mirror of the vehicle.

The eye ellipse, which is actually an ellipsoid, is rarely achieved by the actions of the driver for a variety of reasons. One specific reason is the poor design of most seat adjustment systems particularly the so-called "4-way-seat". It is known that there are three degrees of freedom of a seat bottom, namely vertical, longitudinal, and rotation about the lateral or pitch axis. The 4-way-seat provides four motions to control the seat: (1) raising or lowering the front of the seat, (2) raising or lowering the back of the seat, (3) raising or lowering the entire seat, (4) moving the seat fore and aft. Such a seat adjustment system causes confusion since there are four control motions for three degrees of freedom. As a result, vehicle occupants are easily frustrated by such events as when the control to raise the seat is exercised, the seat not only is raised but is also rotated. Occupants thus find it difficult to place the seat in the optimum location using this system and frequently give up trying leaving the seat in an improper driving position

Many vehicles today are equipped with a lumbar support system that is never used by most occupants. One reason is that the lumbar support cannot be preset since the shape of the lumbar for different occupants differs significantly, i.e., a tall person has significantly different lumbar support requirements than a short person. Without knowledge of the size of the occupant, the lumbar support cannot be automatically adjusted.

As discussed in the above referenced '320 patent, in approximately 95% of the cases where an occupant suffers a whiplash injury, the headrest is not properly located to protect him or her in a rear impact collision. Also, the stiffness and damping characteristics of a seat are fixed and no attempt is made in any production vehicle to adjust the stiffness and damping of the seat in relation to either the size or weight of an occupant, or to the environmental conditions such as road roughness. All of these adjustments, if they are to be done automatically, require knowledge of the morphology of the seat occupant.

Systems are now being used to attempt to identify the vehicle occupant based on a coded key or other object carried by the occupant. This requires special sensors within the vehicle to recognize the coded object. Also, the system only works if the coded object is used by the particular person for whom the vehicle was programmed. If the vehicle is used by a son or daughter, for example, who use their mother's key then the wrong seat adjustments are made. Also, these systems preserve the choice of seat position without any regard for the correctness of the seat position. With the problems associated with the 4-way seats, it is unlikely that the occupant ever properly adjusts the seat. Therefore, the error will be repeated every time the occupant uses the vehicle.

Moreover, these coded systems are a crude attempt to identify the occupant. An improvement can be made if the morphological characteristics of the occupant can be measured as described below. Such measurements can be made of the height and weight, for example, and used not only to adjust a vehicular component to a proper position but also to remember that position, as fine tuned by the occupant, for re-positioning the component the next time the occupant occupies the seat. For the purposes herein, a morphological characteristic will mean any measurable property of a human such as height, weight, leg or arm length, head diameter, facial features, iris patterns, voice, finger or hand prints etc.

As discussed more fully below, in a preferred implementation, once at least one and preferably two of the morphological characteristics of a driver are determined, e.g., by measuring his or her height and weight, the component such as the seat can be adjusted and other features or components can be incorporated into the system including, for example, the automatic adjustment of the rear view and/or side mirrors based on seat position and occupant height. In addition, a determination of an out-of-position occupant can be made and based thereon, airbag deployment suppressed if the occupant is more likely to be injured by the airbag than by the accident without the protection of the airbag. Furthermore, the characteristics of the airbag including the amount of gas produced by the inflator and the size of the airbag exit orifices can be adjusted to provide better protection for small lightweight occupants as well as large, heavy people. Even the direction of the airbag deployment can, in some cases, be controlled.

Still other features or components can now be adjusted based on the measured occupant morphology as well as the fact that the occupant can now be identified. Some of these features or components include the adjustment of seat armrest, cup holder, steering wheel (angle and telescoping), pedals, visors phone location and for that matter the adjustment of all things in the vehicle which a person must reach or interact with. Some items that depend on personal preferences can also be automatically adjusted including the radio station, temperature, ride and others.

"Pattern recognition" as used herein will generally mean any system which processes a signal that is generated by an

object (e.g., representative of a pattern of returned or received impulses, waves or other physical property specific to and/or characteristic of and/or representative of that object) or is modified by interacting with an object, in order to determine to which one of a set of classes that the object belongs. Such a system might determine only that the object is or is not a member of one specified class, or it might attempt to assign the object to one of a larger set of specified classes, or find that it is not a member of any of the classes in the set. The signals processed are generally a series of electrical signals coming from transducers that are sensitive to acoustic (ultrasonic) or electromagnetic radiation (e.g., visible light, infrared radiation, radar, or any other frequency), although other sources of information are frequently included.

A trainable or a trained pattern recognition system as used herein generally means a pattern recognition system which is taught to recognize various patterns constituted within the signals by subjecting the system to a variety of examples. The most successful such system is the neural network or modular neural network. Thus, to generate the pattern recognition algorithm, test data is first obtained which constitutes a plurality of sets of returned waves, or wave patterns or other data, from an object (or from the space in which the object will be situated in the passenger compartment, i.e., the space above the seat) and an indication of the identity of that object, (e.g., a number of different objects are tested to obtain the unique wave patterns from each object). As such, the algorithm is generated, and stored in a computer processor, and which can later be applied to provide the identity of an object based on the wave or other pattern being received during use by a receiver connected to the processor and other information. For the purposes here, the identity of an object sometimes applies to not only the object itself but also to its location and/or orientation in the passenger compartment. For example, a rear facing child seat is a different object than a forward facing child seat and an out-of-position adult is a different object than a normally seated adult.

Other means of pattern recognition exist where the training is done by the researcher including Fuzzy Logic and Sensor Fusion systems.

To "identify" as used herein will generally mean to determine that the object belongs to a particular set or class. The class may be one containing, for example, all rear facing child seats, one containing all human occupants, or all human occupants not sitting in a rear facing child seat depending on the purpose of the system. In the case where a particular person is to be recognized, the set or class will contain only a single element, i.e., the person to be recognized.

To "ascertain the identity of" as used herein with reference to an object will generally mean to determine the type or nature of the object (obtain information as to what the object is), i.e., that the object is an adult, an occupied rear facing child seat, an occupied front facing child seat, an unoccupied rear facing child seat, an unoccupied front facing child seat, a child, a dog, a bag of groceries, etc.

An "object" or "occupying item" of a seat may be a living occupant such as a human or a dog, another living organism such as a plant, or an inanimate object such as a box or bag of groceries or an empty child seat.

"Out-of-position" as used for an occupant will generally mean that the occupant, either the driver or a passenger, is sufficiently close to the occupant protection apparatus (airbag) prior to deployment that he or she is likely to be more seriously injured by the deployment event itself than by the accident. It may also mean that the occupant is not positioned appropriately in order to attain the beneficial, restraining effects of the deployment of the airbag. As for the occupant being too close to the airbag, this typically occurs when the occupant's head or chest is closer than some distance such as about 5 inches from the deployment door of the airbag module. The actual distance value where airbag deployment should be suppressed depends on the design of the airbag module and is typically farther for the passenger airbag than for the driver airbag.

"Transducer" as used herein will generally mean the combination of a transmitter and a receiver. In some cases, the same device will serve both as the transmitter and receiver while in others two separate devices adjacent to each other will be used. In some cases, a transmitter is not used and in such cases transducer will mean only a receiver. Transducers include, for example, capacitive, inductive, ultrasonic, electromagnetic (antenna, CCD, CMOS arrays), weight measuring or sensing devices.

"Adaptation" as used here represents the method by which a particular occupant sensing system is designed and arranged for a particular vehicle model. It includes such things as the process by which the number, kind and location of various transducers is determined. For pattern recognition systems, it includes the process by which the pattern recognition system is taught to recognize the desired patterns. In this connection, it will usually include (1) the method of training, (2) the makeup of the databases used for training, testing and validating the particular system, or, in the case of a neural network, the particular network architecture chosen, (3) the process by which environmental influences are incorporated into the system, and (4) any process for determining the pre-processing of the data or the post processing of the results of the pattern recognition system. The above list is illustrative and not exhaustive. Basically, adaptation includes all of the steps that are undertaken to adapt transducers and other sources of information to a particular vehicle to create the system that accurately identifies and determines the location of an occupant or other object in a vehicle.

Heretofore, various methods have been proposed for measuring the weight of an occupying item of a vehicular seat. The methods include pads, sheets or films that have placed in the seat cushion which attempt to measure the pressure distribution of the occupying item. Prior to its first disclosure in U.S. Pat. No. 5,822,707 referenced above, systems for measuring occupant weight based on the strain in the seat structure had not been considered. Prior art weight measurement systems have been notoriously inaccurate. Thus, a more accurate weight measuring system is desirable. The strain and bladder weight measurement systems described herein, substantially eliminate the inaccuracy problems of prior art systems and permit an accurate determination of the weight of the occupying item of the vehicle seat. Additionally, as disclosed herein, in many cases, sufficient information can be obtained for the control of a vehicle component without the necessity of determining the entire weight of the occupant. For example, the force that the occupant exerts on one of the three support members may be sufficient.

A "vehicle" as used herein will generally mean a self-propelled land vehicle such as a car, truck or bus, but can also encompass airplanes, trains (locomotives and non-self-propelled cars), boats and non-self-propelled and vehicles such as truck trailers.

Most, if not all, of the problems discussed above are difficult to solve or unsolvable using conventional technology.

OBJECTS OF THE INVENTION

Accordingly, it is a principal object of the present invention to provide new and improved apparatus and methods for measuring the weight of an occupying item on a vehicle seat which apparatus and methods may be integrated into vehicular component adjustment apparatus and methods which evaluate the occupancy of the seat and adjust the location and/or orientation relative to the occupant and/or operation of a part of the component or the component in its entirety based on the evaluated occupancy of the seat.

It is another object of the present invention to provide new and improved vehicular seats including a weight measuring feature and weight measuring methods for implementation in connection with vehicular seats.

It is another object of the present invention to obtain a measurement of the weight of an occupying item in a seat of a vehicle while compensating for effects caused by a seatbelt, road roughness, steering maneuvers and a vehicle suspension system.

It is yet another object of the present invention to classify an occupying item in a seat based on dynamic forces measured by a weight sensor associated with the seat, with an optional compensation for effects caused by the seatbelt, road roughness, etc.

It is still another object of the present invention to determine whether an occupying item is belted based on dynamic forces measured by a weight sensor associated with the seat, with an optional compensation for effects caused by the seatbelt, road roughness, etc.

It is still another object of the present invention to determine whether an occupying item in the seat is alive or inanimate based on dynamic forces measured by a weight sensor associated with the seat, with an optional compensation for effects caused by the seatbelt, road roughness, etc.

It is yet another object of the invention to determine the location of the occupying item on a seat based on dynamic forces measured by a weight sensor associated with the seat, with an optional compensation for effects caused by the seatbelt, road roughness, etc.

Additional objects and advantages of this invention include:

1. to provide new and improved vehicular seats in which the weight applied by an occupying item to the seat is measured based on capacitance between conductive and/or metallic members underlying the seat cushion.

2. to provide new and improved adjustment apparatus and methods that evaluate the occupancy of the seat and adjust the location and/or orientation relative to the occupant and/or operation of a part of the component or the component in its entirety based on the evaluated occupancy of the seat and on a measurement of the occupant's weight or a measurement of a force exerted by the occupant on the seat.

3. to provide new and improved adjustment apparatus and methods that evaluate the occupancy of the seat by a combination of ultrasonic sensors and additional sensors and adjust the location and/or orientation relative to the occupant and/or operation of a part of the component or the component in its entirety based on the evaluated occupancy of the seat.

4. to provide new and improved adjustment apparatus and methods that reliably discriminate between a normally seated passenger and a forward facing child seat, between an abnormally seated passenger and a rear facing child seat, and whether or not the seat is empty and adjust the location and/or orientation relative to the occupant and/or operation of a part of the component or the component in its entirety based thereon.

5. to provide an improved weight measurement system and thereby improve the accuracy of another apparatus or system which utilizes measured weight as input, e.g., a component adjustment apparatus.

6. to provide new and improved adjustment apparatus and methods that evaluate the occupancy of the seat without the problems mentioned above.

7. to provide a system for passively and automatically adjusting the position of a vehicle component to a near optimum location based on the size of an occupant.

8. to provide a system for recognizing a particular occupant of a vehicle and thereafter adjusting various components of the vehicle in accordance with the preferences of the recognized occupant.

9. to provide systems for approximately locating the eyes of a vehicle driver to thereby permit the placement of the driver's eyes at a particular location in the vehicle.

10. to provide a pattern recognition system to permit more accurate location of an occupant's head and the parts thereof and to use this information to adjust a vehicle component.

11. to provide a method of determining whether a seat is occupied and, if not, leaving the seat at a neutral position.

12. to provide a system for automatically adjusting the position of various components of the vehicle to permit safer and more effective operation of the vehicle including the location of the pedals and steering wheel.

13. to determine whether an occupant is out-of-position relative to the airbag and if so, to suppress deployment of the airbag in a situation in which the airbag would otherwise be deployed.

14. to adjust the flow of gas into and/or out of the airbag based on the morphology and position of the occupant to improve the performance of the airbag in reducing occupant injury.

15. to provide a system where the morphological characteristics of an occupant are measured by sensors located within the seat.

16. to provide a system and method wherein the weight of an occupant is determined utilizing sensors located on the seat structure.

17. to provide a system and method wherein other morphological properties are used to identify an individual including facial features, iris patterns, voiceprints, fingerprints and handprints.

Further objects of the present invention will become apparent from the following discussion of the preferred embodiments of the invention.

SUMMARY OF THE INVENTION

Accordingly, to achieve at least one of the above objects, an arrangement for determining weight of an occupying item in a seat comprises at least one weight sensor arranged to obtain a measurement of the force applied to the seat, a forcing function determination arrangement for measuring a forcing function of the seat and a processor coupled to the weight sensor(s) and forcing function determination arrangement for receiving the measurement of the force applied to the weight sensor(s) and the measurement of the forcing function from the forcing function measurement system and determining the weight of the occupying item based thereon.

The forcing function determination arrangement may comprise at least one accelerometer, for example, a vertical accelerometer. The forcing function determination arrange-

ment may be arranged to measure effects on the seat caused by load of a seatbelt associated with the seat whereby the forcing function is dependent on the load caused by the seatbelt. Also, the forcing function determination arrangement can measure effects on the seat of road roughness, steering maneuvers, and a vehicle suspension system whereby the forcing function is dependent on the road roughness, steering maneuvers and the vehicle suspension system.

The weight sensors may be of various, different types including a bladder having at least one chamber and at least one transducer for measuring the pressure in a respective chamber.

The processor can be designed or programmed to determine whether the occupying item is belted by analyzing the measurements from by the weight sensor(s) over time and the forcing function of the seat from the forcing function determination arrangement over time. Also, the processor can be designed or programmed to differentiate between animate and inanimate objects by analyzing measurements from the weight sensor(s) over time and the forcing function of the seat from the forcing function determination arrangement over time. In addition, the processor can be designed or programmed to determine the position of the occupying item on the seat by analyzing the measurements from the weight sensor(s) over time and the forcing function of the seat from the forcing function determination arrangement over time

Another arrangement for determining weight of an occupying item in a seat comprises at least one weight sensor arranged to obtain a measurement of the force applied to the seat by the occupying item, a measuring system for measuring dynamic forces being applied to the seat and a processor coupled to the weight sensor(s) and measuring system for receiving the measurement of the force applied to the seat from the weight sensor(s) and the dynamic forces from the measuring system and determining the weight of the occupying item based thereon.

The measuring system may comprise at least one accelerometer, for example, a vertical accelerometer. It also may be arranged to measure effects on the seat caused by load of a seatbelt associated with the seat and/or effects on the seat of road roughness, steering maneuvers, and a vehicle suspension system.

The weight sensors may be of various, different types including a bladder having at least one chamber and at least one transducer for measuring the pressure in a respective chamber.

The processor can be designed or programmed to determine whether the occupying item is belted by analyzing the measurements from by the weight sensor(s) over time and the dynamic forces applied to the seat by the measuring system over time. Also, the processor can be designed or programmed to differentiate between animate and inanimate objects by analyzing measurements from the weight sensor(s) over time and the dynamic forces applied to the seat by the measuring system over time. In addition, the processor can be designed or programmed to determine the position of the occupying item on the seat by analyzing the measurements from the weight sensor(s) over time and the dynamic forces applied to the seat by the measuring system over time

An arrangement for classifying an occupying item in a seat in accordance with the invention comprises at least one weight sensor arranged to measure the force applied to the seat at time intervals and a processor coupled to the weight sensor(s) for receiving the force measurements therefrom. The processor analyzes the force measurements from the weight sensor(s) over time to discern patterns providing classification information about the occupying item. More particularly, the processor may be trained to discern patterns providing information about the occupying item by conducting tests in which different occupying items are placed in the seat and measurements of the force applied to the seat are obtained by the weight sensor(s), before, during and after placement of the occupying item in the seat.

A forcing function determination arrangement may be provided and coupled to the processor for measuring a forcing function of the seat. The processor then considers the forcing function in the discerning of the patterns providing classification information about the occupying item.

A measuring system can also be coupled to the processor for measuring dynamic forces applied to the seat. The processor would then consider the dynamic forces applied to the seat in the discerning of the patterns providing classification information about the occupying item.

To achieve one or more objects of the invention, a method for determining weight of an occupying item in a seat of a vehicle comprises the steps of measuring the force applied to the seat, measuring a forcing function of the seat, and determining the weight of the occupying item based on the measured force applied to the seat and the measured forcing function. The features of the arrangements described above can be used in connection with this method.

Another method for determining weight of an occupying item in a seat comprises the steps of measuring the force applied to the seat, measuring dynamic forces applied to the seat and determining the weight of the occupying item based on the measured force applied to the seat and the measured dynamic forces applied to the seat. The features of the arrangements described above can be used in connection with this method.

A method for classifying an occupying item in a seat in accordance with the invention comprises the steps of measuring the force applied to the seat at time intervals and identifying patterns indicative of a classification of particular occupying items based on the measurements of the force applied to the seat over time. Identification of such patterns may entail utilizing a pattern recognition algorithm to identify patterns from the measurements of the force applied to the seat over time. For example, the pattern recognition algorithm can be trained by conducting tests in which different occupying items are placed in the seat and measuring the force applied to the seat before, during and after placement of the occupying item in the seat. Further, a forcing function of the seat can be measured so that identification of patterns would additionally entail identifying patterns based on the measurements of the force applied to the seat and the forcing function. Also, dynamic forces applied to the seat may be measured so that identification of patterns might entail identifying patterns based on the measurements of the force applied to the seat and the measurements of the dynamic forces applied to the seat.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings are illustrative of embodiments of the invention and are not meant to limit the scope of the invention as encompassed by the claims.

FIG. 1 shows a seated-state detecting unit in accordance with the present invention and the connections between ultrasonic or electromagnetic sensors, a weight sensor, a reclining angle detecting sensor, a seat track position detect-

ing sensor, a heartbeat sensor, a motion sensor, a neural network circuit, and an airbag system installed within a vehicle compartment;

FIG. 2 is a perspective view of a vehicle showing the position of the ultrasonic or electromagnetic sensors relative to the driver and front passenger seats.;

FIG. 3 is a circuit diagram of the seated-state detecting unit of the present invention;

FIGS. 4(*a*), 4(*b*) and 4(*c*) are each a diagram showing the configuration of the reflected waves of an ultrasonic wave transmitted from each transmitter of the ultrasonic sensors toward the passenger seat, obtained within the time that the reflected wave arrives at a receiver, FIG. 4(*a*) showing an example of the reflected waves obtained when a passenger is in a normal seated-state, FIG. 4(*b*) showing an example of the reflected waves obtained when a passenger is in an abnormal seated-state (where the passenger is seated too close to the instrument panel), and FIG. 4(*c*) showing a transmit pulse;

FIG. 5 is a diagram of the data processing of the reflected waves from the ultrasonic or electromagnetic sensors;

FIG. 6 is a flowchart showing the training steps of a neural network circuit;

FIG. 7(*a*) is an explanatory diagram of a process for normalizing the reflected wave and shows normalized reflected waves; and

FIG. 7(*b*) is a diagram similar to FIG. 7(*a*) showing a step of extracting data based on the normalized reflected waves and a step of weighting the extracted data by employing the data of the seat track position detecting sensor, the data of the reclining angle detecting sensor, and the data of the weight sensor.

FIG. 8 is a perspective view of an automatic seat adjustment system, with the seat shown in phantom, with a movable headrest and sensors for measuring the height of the occupant from the vehicle seat showing motors for moving the seat and a control circuit connected to the sensors and motors.

FIG. 9 is a perspective view of the seat shown in FIG. 8 with the addition of a weight sensor shown mounted onto the seat.

FIG. 9A is a view taken along line 9A—9A in FIG. 9.

FIG. 9B is an enlarged view of the section designated 9B in FIG. 9A.

FIG. 9C is a view of another embodiment of a seat with a weight sensor similar to the view shown in FIG. 9A.

FIG. 9D is a view of another embodiment of a seat with a weight sensor in which a SAW strain gage is placed on the bottom surface of the cushion.

FIG. 10 is a side plan view of the interior of an automobile, with portions cut away and removed, with two occupant height measuring sensors, one mounted into the headliner above the occupant's head and the other mounted onto the A-pillar and also showing a seatbelt associated with the seat wherein the seatbelt has an adjustable upper anchorage point which is automatically adjusted based on the height of the occupant.

FIG. 11 is a view of the seat of FIG. 8 showing motors for changing the tilt of seat back and the lumbar support.

FIG. 12 is a view of the seat of FIG. 8 showing a system for changing the stiffness and the damping of the seat.

FIG. 12A is a view of the seat of FIG. 8 wherein the bladder contains a plurality of chambers.

FIG. 13 is a view as in FIG. 10 showing a driver and driver seat with an automatically adjustable steering column and pedal system which is adjusted based on the morphology of the driver.

FIG. 14 is a perspective view of the interior of the passenger compartment of an automobile, with parts cut away and removed, showing a variety of transmitters that can be used in a phased array system.

FIG. 15 is a view similar to FIG. 8 showing the occupant's eyes and the seat adjusted to place the eyes at a particular vertical position for proper viewing through the windshield and rear view mirror.

FIG. 16 is a view similar to FIG. 8 showing an inflated airbag and an arrangement for controlling both the flow of gas into and the flow of gas out of the airbag during the crash where the determination is made based on a height sensor located in the headrest and a weight sensor in the seat.

FIG. 17A is a schematic drawing of the basic embodiment of the adjustment system in accordance with the invention.

FIG. 17B is a schematic drawing of another basic embodiment of the adjustment system in accordance with the invention.

FIG. 18 is a perspective view of a one embodiment of an apparatus for measuring the weight of an occupying item of a seat illustrating weight sensing transducers mounted on a seat control mechanism portion which is attached directly to the seat.

FIG. 19 illustrates a seat structure with the seat cushion and back cushion removed illustrating a three-slide attachment of the seat to the vehicle and preferred mounting locations on the seat structure for strain measuring weight sensors of an apparatus for measuring the weight of an occupying item of a seat in accordance with the invention.

FIG. 19A illustrates an alternate view of the seat structure transducer mounting location taken in the circle A of FIG. 19 with the addition of a gusset and where the strain gage is mounted onto the gusset.

FIG. 19B illustrates a mounting location for a weight sensing transducer on a centralized transverse support member in an apparatus for measuring the weight of an occupying item of a seat in accordance with the invention.

FIGS. 20A, 20B and 20C illustrate three alternate methods of mounting strain transducers of an apparatus for measuring the weight of an occupying item of a seat in accordance with the invention onto a tubular seat support structural member.

FIG. 21 illustrates an alternate weight sensing transducer utilizing pressure sensitive transducers.

FIG. 21A illustrates a part of another alternate weight sensing system for a seat.

FIG. 22 illustrates an alternate seat structure assembly utilizing strain transducers.

FIG. 22A is a perspective view of a cantilevered beam type load cell for use with the weight measurement system of this invention for mounting locations of FIG. 22, for example.

FIG. 22B is a perspective view of a simply supported beam type load cell for use with the weight measurement system of this invention as an alternate to the cantilevered load cell of FIG. 22A.

FIG. 22C is an enlarged view of the portion designated 22C in FIG. 22B.

FIG. 22D is a perspective view of a tubular load cell for use with the weight measurement system of this invention as an alternate to the cantilevered load cell of FIG. 22A.

FIG. 22E is a perspective view of a torsional beam load cell for use with the weight measurement apparatus in

accordance with the invention as an alternate to the cantilevered load cell of FIG. 22A.

FIG. 23 is a schematic of a vehicle with several accelerometers and/or gyroscopes at preferred locations in the vehicle.

FIG. 24 is a schematic showing the manner in which dynamic forces of the vehicle can be compensated for in a weight measurement of the occupant.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the accompanying drawings wherein like reference numbers designate the same or similar elements, FIG. 1 shows a passenger seat **1** to which an adjustment apparatus including a seated-state detecting unit according to the present invention may be applied. The seat **1** includes a horizontally situated bottom seat portion **2** and a vertically oriented back portion **3**. The seat portion **2** is provided with one or more weight sensors **6** and **7** that determine the weight of the object occupying the seat. The coupled portion between the seated portion **2** and the back portion **3** is provided with a reclining angle detecting sensor **9**, which detects the tilted angle of the back portion **3** relative to the seat portion **2**. The seat portion **2** is provided with a seat track position-detecting sensor **10**. The seat track position detecting sensor **10** fulfills a role of detecting the quantity of movement of the seat **1** which is moved from a back reference position, indicated by the dotted chain line. Embedded within the seatback is a heartbeat sensor **31** and a motion sensor **33**. Attached to the headliner is a capacitance sensor **32**. The seat **1** may be the driver seat, the front passenger seat or any other seat in a motor vehicle as well as other seats in transportation vehicles or seats in non-transportation applications.

Weight measuring means such as the sensors **6** and **7** are associated with the seat, e.g., mounted into or below the seat portion **2** or on the seat structure, for measuring the weight applied onto the seat. The weight may be zero if no occupying item is present. Sensors **6** and **7** may represent a plurality of different sensors which measure the weight applied onto the seat at different portions thereof or for redundancy purposes, e.g., such as by means of an airbag **7** in the seat portion **2**. Such sensors may be in the form of strain, force or pressure sensors which measure the force or pressure on the seat or seat back, displacement measuring sensors which measure the displacement of the seat surface or the entire seat such as through the use of strain gages mounted on the seat structural members, such as **7**, or other appropriate locations, or systems which convert displacement into a pressure wherein a pressure sensor can be used as a measure of weight and/or weight distribution.

Many practical problems have arisen during the development stages of bladder and strain gage based weight systems. Some of these problems relate to bladder sensors and in particular to gas filled bladder sensors and are effectively dealt with in U.S. Pat. Nos. 5,918,696, 5,927,427, 5,957,491, 5,979,585, 5,984,349, 6,021,863, 6,056,079, 6,076,853, 6,260,879 and 6,286,861, all of which are incorporated herein by reference. Other problems relate to seatbelt usage and to unanticipated stresses and strains that occur in seat mounting structures.

As to the latter issue, when an occupant or object is strapped into the seat using a seatbelt, it can cause an artificial load on a bladder type weight sensor and/or strain gage type weight sensors when the seatbelt anchorage points are not on the seat. The effects of seatbelt load can be separated from the effects of object or occupant weight, as disclosed in U.S. Pat. No. 6,242,701, cross-referenced above, if the time varying signals are considered rather than merely using averaging to obtain the static load. If a vehicle-mounted vertical accelerometer is present, then the forcing function on the seat caused by road roughness, steering maneuvers, and the vehicle suspension system can be compared with the response of the seat as measured by the bladder or strain gage weight sensors. Through mathematical analysis, the magnitude of the bladder pressure or strain caused by seat belt loads can be separated from pressure and strain caused by occupant or object mass. Also, since animated objects such as people cannot sit still indefinitely, such occupants can be distinguished from inanimate objects by similarly observing the change in pressure and strain distribution over time.

A serious problem that has plagued researchers attempting to adapt strain gage technology to seat weight sensing arises from fact that a typical automobile seat is an over-determined structure containing indeterminate stresses and strains in the supporting structure. This arises from a variety of causes such as the connection between the seat structure and the slide mechanisms below the seat or between the slide mechanisms and the floor which induces twisting and bending moments in the seat structural members. Similarly, since most seats have four attachment points and since only three points are necessary to determine a plane, there can be an unexpected distribution of compression and tensile stresses in the support structure. To complicate the situation, these indeterminable stresses and strains can vary as a function of seat position and temperature. The combination of all of these effects produces a significant error in the calculation of the weight of an occupying item and the distribution of this weight.

This problem can be solved by looking at changes in pressure and strain readings in addition to the absolute values. The dynamic response of an occupied seat is a function of the mass of the occupying item. As the car travels down the road, a forcing function is provided to the seat which can be measured by the vertical acceleration component and other acceleration components. This provides a method of measuring the response of the seat as well as the forcing function and thereby determining the mass of occupying item.

For example, when an occupant first enters the vehicle and sits on a seat, the change in pressure and/or strain measurements will provide an accurate measurement of the occupant's weight. This accuracy deteriorates as soon as the occupant attaches a seatbelt and/or moves the seat to a new position. Nevertheless, the change in occupancy of the seat is a significant event that can be easily detected and if the change in pressure and strain measurements are used as the measurement of the occupant weight, then the weight can be accurately determined. Similarly, the sequence of events for attaching a child seat to a vehicle is one that can be easily discerned since the seat is first placed into the vehicle and the seat belt cinched followed by placing the child in the seat or, alternately, the child and seat are placed in the vehicle followed by a cinching of the seatbelt. Either of these event sequences gives a high probability of the occupancy being a child in a child seat. This decision can be confirmed by dynamical measurements as described above.

A control system for controlling a component of the vehicle based on occupancy of the seat in accordance with the invention may comprise a plurality of strain gages, or bladder chambers, mounted in connection with the seat, each measuring strain or pressure of a respective location caused

by occupancy of the seat, and a processor coupled to the strain or pressure gages and arranged to determine the weight of an occupying item based on the strain or pressure measurements from the strain or pressure gages over a period of time, i.e., dynamic measurements. The processor controls the vehicle component based at least in part on the determined weight of the occupying item of the seat. The processor can also determine motion of the occupying item of the seat based on the strain or pressure measurements from the strain or pressure gages over the period of time. One or more accelerometers may be mounted on the vehicle for measuring acceleration in which case, the processor may control the component based at least in part on the determined weight of the occupying item of the seat and the acceleration measured by the accelerometer(s). (See the discussion below in reference to FIG. 23.)

By comparing the output of various sensors in the vehicle, it is possible to determine activities that are affecting parts of the vehicle while not affecting other parts. For example, by monitoring the vertical accelerations of various parts of the vehicle and comparing these accelerations with the output of strain gage load cells placed on the seat support structure, or bladder sensors, a characterization can be made of the occupancy of the seat. Not only can the weight of an object occupying the seat be determined, but also the gross motion of such an object can be ascertained and thereby an assessment can be made as to whether the object is a life form such as a human being and whether the seatbelt is engaged. Strain gage weight sensors are disclosed, for example, in U.S. Pat. No. 6,242,701, which is incorporated herein by reference in its entirety as if the entire patent were printed herein. In particular, the inventors contemplate the combination of all of the ideas expressed in the '701 patent with those expressed in the current invention.

Thus, the combination of the outputs from these accelerometer sensors and the output of strain gage or bladder weight sensors in a vehicle seat, or in or on a support structure of the seat, can be used to make an accurate assessment of the occupancy of the seat and differentiate between animate and inanimate occupants as well as determining where in the seat the occupants are sitting and whether the seatbelt is engaged. This can be done by observing the acceleration signals from the sensors of FIG. 23 and simultaneously the dynamic strain gage measurements from seat-mounted strain or pressure gages or pressure measurements of bladder weight sensors. The accelerometers provide the input function to the seat and the strain gages measure the reaction of the occupying item to the vehicle acceleration and thereby provide a method of determining dynamically the mass of the occupying item and its location. This is particularly important during occupant position sensing during a crash event. By combining the outputs of the accelerometers and the strain gages and appropriately processing the same, the mass and weight of an object occupying the seat can be determined as well as the gross motion of such an object so that an assessment can be made as to whether the object is a life form such as a human being and whether a seatbelt is used and if so how tightly it is cinched.

As shown in FIG. 2, there are provided four sets of wave-receiving sensor systems 11–14 mounted within the passenger compartment. Each set of sensor systems 11–14 comprises a transmitter and a receiver, which may be integrated into a single unit or individual components separated from one another. In this embodiment, the sensor system 11 is mounted on the upper portion of the front pillar, A-Pillar, of the vehicle. The sensor system 12 is mounted on

the upper portion of the intermediate pillar, B-Pillar. The sensor system 13 is mounted on the roof ceiling portion or the headliner (FIG. 2). The sensor system 14 is mounted near the middle of an instrument panel 17 in front of the driver's seat 16 (FIG. 2). The sensor systems are preferably ultrasonic or electromagnetic. Although sensor systems 11–14 are described as being ultrasonic or electromagnetic sensors, the invention is equally applicable for other types of sensors (other than ultrasonic or electromagnetic) which will detect the presence of an occupant from a distance including capacitive, electric field or other electromagnetic sensors. Also, if the sensor systems 11–14 are passive infrared sensors, then they may only comprise a wave-receiver.

The ultrasonic or electromagnetic sensor systems 11–14 are controlled or driven, one at a time or simultaneously, by an appropriate driver circuit such as ultrasonic or electromagnetic sensor driver circuit 18 shown in FIG. 3. The transmitters of the ultrasonic or electromagnetic sensor systems 11–14 transmit respective ultrasonic or electromagnetic waves toward the seat 1 and transmit pulses (see FIG. 4(*c*)) in sequence at times t1, t2, t3 and t4 (t4>t3>t2>t1) or simultaneously (t1=t2=t3=t4) The reflected waves of the ultrasonic or electromagnetic waves are received by the receivers ChA–ChD of the ultrasonic or electromagnetic sensors 11–14. The receiver ChA is associated with the ultrasonic or electromagnetic sensor system 13, the receiver ChB is associated with the ultrasonic or electromagnetic sensor system 14, the receiver ChD is associated with the ultrasonic or electromagnetic sensor system 11, and the receiver ChD is associated with the ultrasonic or electromagnetic sensor system 12.

The following discussion will apply to the case where ultrasonic sensors are used although a similar discussion can be presented relative to the use of electromagnetic sensors such as active infrared sensors, taking into account the differences in the technologies. Also, the following discussion will relate to an embodiment wherein the seat 1 is the front passenger seat. FIGS. 4(*a*) and 4(*b*) show examples of the reflected ultrasonic waves USRW that are received by receivers ChA–ChD. FIG. 4(*a*) shows an example of the reflected wave USRW that is obtained when an adult sits in a normally seated space on the passenger seat 1, while FIG. 4(*b*) shows an example of the reflected wave USRW that are obtained when an adult sits in a slouching state (one of the abnormal seated-states) in the passenger seat 1.

In the case of a normally seated passenger, as shown in FIG. 2, the location of the ultrasonic sensor system 12 is closest to the passenger A. Therefore, the reflected wave pulse P1 is received earliest after transmission by the receiver ChD as shown in FIG. 4(*a*), and the width of the reflected wave pulse P1 is larger. Next, the distance from the ultrasonic sensor 13 is closer to the passenger A, so a reflected wave pulse P2 is received earlier by the receiver ChA compared with the remaining reflected wave pulses P3 and P4. Since the reflected wave pauses P3 and P4 take more time than the reflected wave pulses P1 and P2 to arrive at the receivers ChC and ChB, the reflected wave pulses P3 and P4 are received as the timings shown in FIG. 4(*a*). More specifically, since it is believed that the distance from the ultrasonic sensor system 11 to the passenger A is slightly shorter than the distance from the ultrasonic sensor system 14 to the passenger A, the reflected wave pulse P3 is received slightly earlier by the receiver ChC than the reflected wave pulse P4 is received by the receiver ChB.

In the case where the passenger A is sitting in a slouching state in the passenger seat 1, the distance between the ultrasonic sensor system 11 and the passenger A is shortest.

Therefore, the time from transmission at time t3 to reception is shortest, and the reflected wave pulse P3 is received by the receiver ChC, as shown in FIG. 4(*b*). Next, the distances between the ultrasonic sensor system **14** and the passenger A becomes shorter, so the reflected wave pulse P4 is received earlier by the receiver ChB than the remaining reflected wave pulses P2 and P1. When the distance from the ultrasonic sensor system **13** to the passenger A is compared with that from the ultrasonic sensor system **12** to the passenger A, the distance from the ultrasonic sensor system **13** to the passenger A becomes shorter, so the reflected wave pulse P2 is received by the receiver ChA first and the reflected wave pulse **1** is thus received last by the receiver ChD.

The configurations of the reflected wave pulses P1–P4, the times that the reflected wave pulses P1–P4 are received, the sizes of the reflected wave pulses P1–P4 are varied depending upon the configuration and position of an object such as a passenger situated on the front passenger seat **1**. FIGS. 4(*a*) and (*b*) merely show examples for the purpose of description and therefore it is a matter of course that the present invention is not limited to these examples.

The outputs of the receivers ChA–ChD, as shown in FIG. **3**, are input to a band pass filter **20** through a multiplex circuit **19** which is switched in synchronization with a timing signal from the ultrasonic sensor drive circuit **18**. The band pass filter **20** removes a low frequency wave component from the output signal based on each of the reflected wave USRW and also removes some of the noise. The output signal based on each of the reflected wave USRW is passed through the band pass filter **20**, then is amplified by an amplifier **21**. The amplifier also removes the high frequency carrier wave component in each of the reflected USRW and generates an envelope wave signal. This envelope wave signal is input to an analog/digital converter (ADC) **22** and digitized as measured data. The measured data is input to a processing circuit **23**, which is controlled by the timing signal which is in turn output from the ultrasonic sensor drive circuit **18**.

The processing circuit **23** collects measured data at intervals of 7 ms, and 47 data points are generated for each of the ultrasonic sensor systems **11**–**14**. For each of these reflected waves USRW, the initial reflected wave portion T1 and the last reflected wave portion T2 are cut off. The reason for this will be described when the training procedure of a neural network circuit is described later, and the description is omitted for now. With this, 32 data points, 31 data points, 37 data points, and 38 data points will be sampled by the ultrasonic sensor systems **11**, **12**, **13** and **14**, respectively. The reason why the number of data points differs for each of the ultrasonic sensor systems **11**–**14** is that the distance from the passenger seat **1** to the ultrasonic sensor systems **11**–**14** differ from one another.

Each of the measured data is input to a normalization circuit **24** and normalized. The normalized measured data is input to the neural network circuit **25** as wave data.

The output of the weight sensor(s) **6** and **7** is amplified by an amplifier **26** coupled to the weight sensor(s) **6** and **7** and the amplified output is input to the analog/digital converter **27**.

The reclining angle detecting sensor **9** and the seat track position-detecting sensor **10**, which each may comprise a variable resistor, and can be connected to constant-current circuits, respectively. A constant-current can be supplied from the constant-current circuit to the reclining angle detecting sensor **9**, and the reclining angle detecting sensor **9** converts a change in the resistance value on the tilt of the back portion **3** to a specific voltage. This output voltage is input to an analog/digital converter **28** as angle data, i.e., representative of the angle between the back portion **3** and the seat portion **2**. Similarly, a constant current can be supplied from the constant-current circuit to the seat track position-detecting sensor **10** and the seat track position detecting sensor **10** converts a change in the resistance value based on the track position of the seat portion **2** to a specific voltage. This output voltage is input to an analog/digital converter **29** as seat track data. Thus, the outputs of the reclining angle-detecting sensor **9** and the seat track position-detecting sensor **10** are input to the analog/digital converters **28** and **29**, respectively. Each digital data value from the ADCs **28**,**29** is input to the neural network circuit **25**. Although the digitized data of the weight sensor(s) **6** and **7** is input to the neural network circuit **25**, the output of the amplifier **26** is also input to a comparison circuit. The comparison circuit, which is incorporated in the gate circuit algorithm, determines whether or not the weight of an object on the passenger seat **1** is more than a predetermined weight, such as 60 lbs., for example. When the weight is more than 60 lbs., the comparison circuit outputs a logic 1 to the gate circuit to be described later. When the weight of the object is less than 60 lbs., a logic **0** is output to the gate circuit.

A heartbeat sensor **31** is arranged to detect a heartbeat, and the magnitude thereof, of a human occupant of the seat, if such a human occupant is present. The output of the heartbeat sensor **31** is input to the neural network circuit **25**. The heartbeat sensor **31** may be of the type as disclosed in McEwan (U.S. Pat. Nos. 5,573,012 and 5,766,208 which are incorporated herein in their entirety by reference)) or based on noise radar technology. The heartbeat sensor **31** can be positioned at any convenient position relative the seat **1** where occupancy is being monitored. A preferred location is within the vehicle seatback for an MIR and in the headliner for a noise radar type device.

A capacitive or electric field sensor **32** is arranged to detect the presence of an occupying item on the seat **1** and the output thereof is input to the neural network circuit **25**. Capacitor or electric field sensors appropriate for this function are disclosed in Kithil (U.S. Pat. No. 5,602,734, which is incorporated herein by reference) and Jinno et al (U.S. Pat. No. 5,948,031, which is incorporated herein by reference). Capacitive sensors can in general be mounted at locations **11**–**14** in FIG. **2** or in the vehicle seat or seatback although by their nature they can occupy considerably more space than shown in the drawings.

A motion sensor **33** is arranged to detect motion of an occupying item on the seat **1** and the output thereof is input to the neural network circuit **25**. Motion sensors can utilize a micro-power impulse radar (MIR) system as disclosed, for example, in McEwan (U.S. Pat. No. 5,361,070, which is incorporated herein by reference), as well as many other patents by the same inventor or by noise radar. Motion sensing is accomplished by monitoring a particular range from the sensor as disclosed in that patent. MIR is one form of radar which has applicability to occupant sensing and can be mounted at locations such as **11**–**14** in FIG. **2**. It has an advantage over ultrasonic sensors in that data can be acquired at a higher speed and thus the motion of an occupant can be more easily tracked. The ability to obtain returns over the entire occupancy range is somewhat more difficult than with ultrasound resulting in a more expensive system overall. MIR or noise radar has additional advantages in lack of sensitivity to temperature variation and can have a comparable resolution to about 40 kHz ultrasound.

Resolution comparable to higher frequency is also feasible. Additionally, multiple MIR sensors can be used when high speed tracking of the motion of an occupant during a crash is required since they can be individually pulsed without interfering with each other through time or code division multiplexing.

The neural network circuit **25** recognizes the seated-state of a passenger A by training as described in several books on Neural Networks referenced in the above referenced patents and patent applications. Then, after training the seated-state of the passenger A and developing the neural network weights, the system is tested. The training procedure and the test procedure of the neural network circuit **25** will hereafter be described with a flowchart shown in FIG. **6**.

As diagrammed in FIG. **6**, the first step is to mount the four sets of ultrasonic sensor systems **11–14**, the weight sensors **6** and **7**, the reclining angle detecting sensor **9**, and the seat track position detecting sensor **10** into a vehicle (step S1). Next, in order to provide data for the neural network circuit **25** to learn the patterns of seated states, data is recorded for patterns of all possible seated states and a list is maintained recording the seated states for which data was acquired. The data from the sensors/transducers **6, 7, 9–14** and **31–33**, for a particular occupancy of the passenger seat is called a vector (step S2). It should be pointed out that the use of the reclining angle detecting sensor **9**, seat track position detecting sensor **10**, heartbeat sensor **31**, capacitive sensor **32** and motion sensor **33** are not essential to the detecting apparatus and method in accordance with the invention. However, each of these sensors, in combination with any one or more of the other sensors enhances the evaluation of the seated-state of the seat.

For the vectors of data, adults and children each with different postures, states of windows etc. within the passenger compartment, and occupied and unoccupied child seats were selected. The selected adults include people with a variety of different physiques such as fat, lean, small, large, tall, short, and glasses wearing persons. The selected children ranged from an infant to a large child (for example, about 14 year old). In addition, the selected postures include, for example, a sitting state with legs crossed on a seat, a sitting state with legs on an instrument panel, a sitting state while reading a newspaper, a book, or a map, a sitting state while holding a cup of coffee, a cellular telephone or a dictation machine, and a slouching state with and without raised knees. Furthermore, the selected compartment states include variations in the seat track position, the window-opening amount, headrest position, and varying positions of a sun-visor. Moreover, a multitude of different models of child seats are used in the forward facing position and, where appropriate, in a rear facing position. In this example, the range of weights and the corresponding normalized values are as follows:

Class	Weight Range	Normalized Value
Empty Seat	0 to 2.2 lbs.	0 to 0.01
Rear Facing Child Seat	2.2 to 60 lbs.	0.01 to 0.27
Forward Facing Child Seat	2.2 to 60 lbs.	0.01 to 0.27
Normal Position Adult	60 lbs and greater	0.27 to 1

Obviously, other weight ranges may also be used in accordance with the invention and each weight range may be tailored to specific conditions, such as different vehicles. The output of the weight sensors may not correspond directly to be weight ranges in the above table. If for example strain measuring sensors are placed on each of the vehicle seat supports, such sensors will also respond to the weight of the seat itself That weight must therefore the remove so that only the additional weight of an occupying item is measured. Similarly it may be desirable to place strain-sensing devices on only some of the vehicle seat support structures. In such cases the weight of the occupying item can be in inferred from the output of the strain sensing sensors. This will be described in greater detail below.

Various vehicle setups were prepared by a combination of these variations and, for in this embodiment, almost 500,000 or more vectors should be prepared for the patterns to be used as data for the neural network training.

Next, based on the training data from the reflected waves of the ultrasonic sensor systems **11–14** and the other sensors **6, 7, 31–33**, the vector data is collected (step S3). Next, the reflected waves P1–P4 are modified by removing the initial reflected waves with a short reflection time from an object (range gating) (period T1 in FIG. **5**) and the last portion of the reflected waves with a long reflection time from an object (period P2 in FIG. **5**) (step S4). It is believed that the reflected waves with a short reflection time from an object is a due to cross-talk, that is, waves from the transmitters which leaks into each of their associated receivers ChA–ChD. It is also believed that the reflected waves with a long reflection time are reflected waves from an object far away from the passenger seat or from multipath reflections. If these two reflected wave portions are used as data, they will add noise to the training process. Therefore, these reflected wave portions are eliminated from the data.

As shown in FIG. **7**(*a*), measured data is normalized by making the peaks of the reflected wave pulses P1–P4 equal (step S5). This eliminates the effects of different reflectivities of different objects and people depending on the characteristics of their surfaces such as their clothing Data from the weight sensor, seat track position sensor and seat recling angle sensor are also frequently normalized based typically on fixed normalization parameters.

The data from the transducers are now also preferably fed through a logaritmic or equivalent compression circuit that substantially reduces the magnitude of reflected signals from high reflectivity targets compared to those of low reflectivity. Additionally, a time gain circuit is used to compensate for the difference in sonic strength received by the transducer based on the distance of the reflecting object from the transducer.

Therefore, the normalized data from the ultrasonic transducers the seat track position detecting sensor **10**, the reclining angle detecting sensor **9**, from the weight sensor(s) **6** and **7**, from the heartbeat sensor **31**, the capacitive sensor **32** and the motion sensor **33** are input to the neural network circuit **25**, and the neural network circuit **25** is then trained on this data. More specifically, the neural network circuit **25** adds up the normalized data from the ultrasonic transducers, from the seat track position detecting sensor **10**, from the reclining angle detecting sensor **9**, from the weight sensor(s) **6** and **7**, from the heartbeat sensor **31**, from the capacitive sensor **32** and from the motion sensor **33** with each data point multiplied by a associated weight according to the conventional neural network process to determine correlation function (step S6).

In this embodiment, 144 data points are appropriately interconnected at 25 connecting points of layer **1**, and each data point is mutually correlated through the neural network training and weight determination process. The 144 data points consist of 138 measured data points from the ultra-

sonic transducers, the data (139th) from the seat track position detecting sensor **10**, the data (140th) from the reclining angle detecting sensor **9**, the data (141st) from the weight sensor(s) **6**, the data (142^{nd}) from the heartbeat sensor **31**, the data (143^{rd}) from the capacitive sensor and the data (144^{th}) from the motion sensor. Each of the connecting points of the layer **1** has an appropriate threshold value, and if the sum of measured data exceeds the threshold value, each of the connecting points will output a signal to the connecting points of layer **2**. Although the weight sensor input is shown as a single input, in general there will be a separate input from each weight sensor used. For example, if the seat has four seat supports and if a strained measuring element is used on each support, what will be four data inputs to neural network.

The connecting points of the layer **2** comprises 20 points, and the 25 connecting points of the layer **1** are appropriately interconnected as the connecting points of the layer **2**. Similarly, each data is mutually correlated through the training process and weight determination as described above and in the above referenced neural network texts. Each of the 20 connecting points of the layer **2** has an appropriate threshold value, and if the sum of measured data exceeds the threshold value, each of the connecting points will output a signal to the connecting points of layer **3**.

The connecting points of the layer **3** comprises 3 points, and the connecting points of the layer **2** are interconnected at the connecting points of the layer **3** so that each data is mutually correlated as described above. If the sum of the outputs of the connecting points of layer **2** exceeds a threshold value, the connecting points of the latter **3** will output Logic values (100), (010), and (001) respectively, for example.

The threshold value of each connecting point is determined by multiplying weight coefficients and summing up the results in sequence, and the aforementioned training process is to determine a weight coefficient Wj so that the threshold value (ai) is a previously determined output.

$$ai=\Sigma Wj \cdot Xj \text{ } (j=1 \text{ to } N)$$

wherein Wj is the weight coefficient,

Xj is the data and

N is the number of samples.

Based on this result of the training, the neural network circuit **25** generates the weights for the coefficients of the correlation function or the algorithm (step S **7**).

At the time the neural network circuit **25** has learned a suitable number of patterns of the training data, the result of the training is tested by the test data. In the case where the rate of correct answers of the seated-state detecting unit based on this test data is unsatisfactory, the neural network circuit is further trained and the test is repeated. In this embodiment, the test was performed based on about 600,000 test patterns. When the rate of correct test result answers was at about 98%, the training was ended.

The neural network circuit **25** has outputs **25***a*, **25***b* and **25***c*. Each of the outputs **25***a*, **25***b* and **25***c* outputs a signal of logic 0 or 1 to a gate circuit or algorithm **30**. Based on the signals from the outputs **25***a*, **25***b* and **25***c*, any one of these combination (100), (010) and (001) is obtained. In another preferred embodiment, all data for the empty seat was removed from the training set and the empty seat case was determined based on the output of the weight sensor alone. This simplifies the neural network and improves its accuracy.

In this embodiment, the output (001) correspond to a vacant seat, a seat occupied by an inanimate object or a seat occupied by a pet (VACANT), the output (010) corresponds to a rear facing child seat (RFCS) or an abnormally seated passenger (ASP), and the output (100) corresponds to a normally seated passenger (NSP) or a forward facing child seat (FFCS).

The gate circuit (seated-state evaluation circuit) **30** can be implemented by an electronic circuit or by a computer algorithm by those skilled in the art and the details will not be presented here. The function of the gate circuit **30** is to remove the ambiguity that sometimes results when ultrasonic sensors and seat position sensors alone are used. This ambiguity is that it is sometimes difficult to differentiate between a rear facing child seat (RFCS) and an abnormally seated passenger (ASP), or between a normally seated passenger (NSP) and a forward facing child seat (FFCS). By the addition of one or more weight sensors in the function of acting as a switch when the weight is above or below 60 lbs., it has been found that this ambiguity can be eliminated. The gate circuit therefore takes into account the output of the neural network and also the weight from the weight sensor(s) as being above or below 60 lbs. and thereby separates the two cases just described and results in five discrete outputs.

Thus, the gate circuit **30** fulfills a role of outputting five kinds of seated-state evaluation signals, based on a combination of three kinds of evaluation signals from the neural network **25** and superimposed information from the weight sensor(s). The five seated-state evaluation signals are input to an airbag deployment determining circuit that is part of the airbag system and will not be described here. Naturally, as disclosed in the above reference patents and patent applications, the output of this system can also be used to activate a variety of lights or alarms to indicate to the operator of the vehicle the seated state of the passenger. Naturally, the system that has been here described for the passenger side is also applicable for the most part for the driver side.

An alternate and preferred method of accomplishing the function performed by the gate circuit is to use a modular neural network. In this case, the first level neural network is trained on determining whether the seat is occupied or vacant. The input to this neural network consists of all of the data points described above. Since the only function of this neural network is to ascertain occupancy, the accuracy of this neural network is very high. If this neural network determines that the seat is not vacant, then the second level neural network determines the occupancy state of the seat.

In this embodiment, although the neural network circuit **25** has been employed as an evaluation circuit, the mapping data of the coefficients of a correlation function may also be implemented or transferred to a microcomputer to constitute the valuation circuit (see Step S **8** in FIG. **6**).

According to the seated-state detecting unit of the present invention, the identification of a vacant seat (VACANT), a rear facing child seat (RFCS), a forward facing child seat (FFCS), a normally seated adult passenger (NSP), an abnormally seated adult passenger (ASP), can be reliably performed. Based on this identification, it is possible to control a component, system or subsystem in the vehicle. For example, a regulation valve which controls the inflation or deflation of an airbag may be controlled based on the evaluated identification of the occupant of the seat. This regulation valve may be of the digital or analog type. A digital regulation valve is one that is in either of two states, open or closed. The control of the flow is then accomplished by varying the time that the valve is open and closed, i.e., the duty cycle.

Moreover, the seated-state detecting unit described above may be used in a component adjustment system and method described below when the presence of a human being occupying the seat is detected.

The component adjustment system and methods in accordance with the invention automatically and passively adjust the component based on the morphology of the occupant of the seat. As noted above, the adjustment system may include the seated-state detecting unit described above so that it will be activated if the seated-state detecting unit detects that an adult or child occupant is seated on the seat, i.e., the adjustment system will not operate if the seat is occupied by a child seat, pet or inanimate objects. Obviously, the same system can be used for any seat in the vehicle including the driver seat and the passenger seat(s). This adjustment system may incorporated the same components as the seated-state detecting unit described above, i.e., the same components may constitute a part of both the seated-state detecting unit and the adjustment system, e.g., the weight measuring means.

The adjustment system described herein, although improved over the prior art, will at best be approximate since two people, even if they are identical in all other respects, may have a different preferred driving position or other preferred adjusted component location or orientation. A system that automatically adjusts the component, therefore, must learn from its errors. Thus, when a new occupant sits in the vehicle, for example, the system automatically estimates the best location of the component for that occupant and moves the component to that location, assuming it is not already at the best location. If the occupant changes the location, the system must remember that change and incorporate it into the adjustment the next time that person enters the vehicle and is seated in the same seat. Therefore, the system need not make a perfect selection the first time but it must remember the person and the position the component was in for that person. The system, therefore, makes one, two or three measurements of morphological characteristics of the occupant and then adjusts the component based on an algorithm. The occupant will correct the adjustment and the next time that the system measures the same measurements for those measurement characteristics, it will set the component to the corrected position. As such, preferred components for which the system in accordance with the invention is most useful are those which affect a driver of the vehicle and relate to the sensory abilities of the driver, i.e., the mirrors, the seat, the steering wheel and steering column and accelerator, clutch and brake pedals.

The first characteristic used is a measurement of the height of the occupant from the vehicle seat. This can be done by a sensor in the ceiling of the vehicle but this becomes difficult since, even for the same seat location, the head of the occupant will not be at the same angle with respect to the seat and therefore the angle to a ceiling mounted sensor is in general unknown at least as long as only one ceiling mounted sensor is used. This problem can be solved if two or three sensors are used as described in more detail below. An alternate implementation is to place the sensor in the seat. In the '320 patent mentioned above, a rear impact occupant protection apparatus is disclosed which uses sensors mounted within the headrest. This same system can also be used to measure the height of the occupant from the seat and thus, for no additional cost assuming the rear impact occupant protection system described in the '320 patent is provided, the first measure of the occupant's morphology can be achieved. For some applications, this may be sufficient since it is unlikely that two operators will use the vehicle who have the same height. For other implementations, one or more additional measurements are used. Naturally, a face, fingerprint or iris recognition system will have the least problem identifying a previous occupant.

Referring now to FIG. **8**, an automatic adjustment system for adjusting a seat (which is being used only as an example of a vehicle component) is shown generally at **100** with a movable headrest **111** and ultrasonic sensor **120** and ultrasonic receiver **121** for measuring the height of the occupant of the seat. Power means such as motors **191**, **192**, and **193** connected to the seat for moving the base of the seat, control means such as a control circuit, system or module **150** connected to the motors and a headrest actuation mechanism using motors **160** and **170**, which may be servomotors, are also illustrated. The seat **110** and headrest **111** are shown in phantom. Vertical motion of the headrest **111** is accomplished when a signal is sent from control module **150** to servomotor **160** through a wire **131**. Servomotor **160** rotates lead screw **162** which engages with a threaded hole in member **164** causing it to move up or down depending on the direction of rotation of the lead screw **162**. Headrest support rods **165** and **166** are attached to member **164** and cause the headrest **111** to translate up or down with member **164**. In this manner, the vertical position of the headrest can be controlled as depicted by arrow A—A. Ultrasonic transmitter and receiver **120**,**121** may be replaced by other appropriate wave-generating and receiving devices, such as electromagnetic, active infrared transmitters and receivers.

Wire **132** leads from control module **150** to servomotor **170** which rotates lead screw **172**. Lead screw **172** engages with a threaded hole in shaft **173** which is attached to supporting structures within the seat shown in phantom. The rotation of lead screw **172** rotates servomotor support **161**, upon which servomotor **160** is situated, which in turn rotates headrest support rods **165** and **166** in slots **168** and the seat **110**. Rotation of the servomotor support **161** is facilitated by a rod **171** upon which the servomotor support **161** is positioned. In this manner, the headrest **111** is caused to move in the fore and aft direction as depicted by arrow B—B. Naturally there are other designs which accomplish the same effect in moving the headrest up and down and fore and aft.

The operation of the system is as follows. When an adult or child occupant is seated on a seat containing the headrest and control system described above as determined by the neural network circuit **25**, the ultrasonic transmitter **120** emits ultrasonic energy which reflects off of the head of the occupant and is received by receiver **121**. An electronic circuit in control module **150** contains a microprocessor which determines the distance from the head of the occupant based on the time between the transmission and reception of an ultrasonic pulse. Control module **150** may be within the same microprocessor as neural network circuit **25** or separate therefrom. The headrest **111** moves up and down until it finds the top of the head and then the vertical position closest to the head of the occupant and then remains at that position. Based on the time delay between transmission and reception of an ultrasonic pulse, the system can also determine the longitudinal distance from the headrest to the occupant's head. Since the head may not be located precisely in line with the ultrasonic sensors, or the occupant may be wearing a hat, coat with a high collar, or may have a large hairdo, there may be some error in this longitudinal measurement.

When an occupant sits on seat **110**, the headrest **111** moves to find the top of the occupant's head as discussed

above. This is accomplished using an algorithm and a microprocessor which is part of control circuit **150**. The headrest **111** then moves to the optimum location for rear impact protection as described in the above referenced '320 patent. Once the height of the occupant has been measured, another algorithm in the microprocessor in control circuit **150** compares the occupant's measured height with a table representing the population as a whole and from this table, the appropriate positions for the seat corresponding to the occupant's height is selected. For example, if the occupant measured 33 inches from the top of the seat bottom, this might correspond to a 85% human, depending on the particular seat and statistical tables of human measurements.

Careful study of each particular vehicle model provides the data for the table of the location of the seat to properly position the eyes of the occupant within the "eye-ellipse", the steering wheel within a comfortable reach of the occupant's hands and the pedals within a comfortable reach of the occupant's feet, based on his or her size, etc.

Once the proper position has been determined by control circuit **150**, signals are sent to motors **191**, **192**, and **193** to move the seat to that position. If during some set time period after the seat has been positioned, the operator changes these adjustments, the new positions of the seat are stored in association with an occupant height class in a second table within control circuit **150**. When the occupant again occupies the seat and his or her height has once again been determined, the control circuit will find an entry in the second table which takes precedence over the basic, original table and the seat returns to the adjusted position. When the occupant leaves the vehicle, or even when the engine is shut off and the door opened, the seat can be returned to a neutral position which provides for easy entry and exit from the vehicle.

The seat **110** also contains two control switch assemblies **180** and **182** for manually controlling the position of the seat **110** and headrest **111**. The seat control switches **180** permit the occupant to adjust the position of the seat if he or she is dissatisfied with the position selected by the algorithm. The headrest control switches **182** permit the occupant to adjust the position of the headrest in the event that the calculated position is uncomfortably close to or far from the occupant's head. A woman with a large hairdo might find that the headrest automatically adjusts so as to contact her hairdo. This adjustment she might find annoying and could then position the headrest further from her head. For those vehicles which have a seat memory system for associating the seat position with a particular occupant, which has been assumed above, the position of the headrest relative to the occupant's head could also be recorded. Later, when the occupant enters the vehicle, and the seat automatically adjusts to the recorded preference, the headrest will similarly automatically adjust (FIG. **17B**).

The height of the occupant, although probably the best initial morphological characteristic, may not be sufficient especially for distinguishing one driver from another when they are approximately the same height. A second characteristic, the occupant's weight, can also be readily determined from sensors mounted within the seat in a variety of ways as shown in FIG. **9** which is a perspective view of the seat shown in FIG. **8** with a displacement or weight sensor **200** shown mounted onto the seat. Displacement sensor **200** is supported from supports **202** and **204**. In general, displacement sensor **200**, or another non-displacement sensor, measures a physical state of a component affected by the occupancy of the seat. An occupying item of the seat will cause a force to be exerted downward

and the magnitude of this force is representative of the weight of the occupying item. Thus, by measuring this force, information about the weight of the occupying item can be obtained. A physical state may be any force changed by the occupancy of the seat and which is reflected in the component, e.g., strain of a component, compression of a component, tension of a component.

Referring now to FIG. **9A**, which is a view of the apparatus of FIG. **9** taken along line **9A**—**9A**, seat **230** is constructed from a cushion or foam layer **232** which is supported by a spring system **234** which is in contact and/or association with the displacement sensor **200**. As shown, displacement sensor **200** is underneath the spring system **234** but this relative positioning is not a required feature of the invention. The displacement sensor **200** comprises an elongate cable **205** retained at one end by support **210** and a displacement sensor **220** situated at an opposite end. This displacement sensor **220** can be any of a variety of such devices including, but not limited to, a linear rheostat, a linear variable differential transformer (LVDT), a linear variable capacitor, or any other length measuring device. Alternately, as shown in FIG. **9C**, the cable can be replaced with one or more springs **242** retained between supports **210** and the tension in the spring measured using a strain gage (conventional wire or foil or a SAW strain gage) or other force measuring device **244** or the strain in the seat support structure can be measured by appropriately placing strain gages on one or more of the seat supports as described in more detail below. The strain gage or other force measuring device could be arranged in association with the spring system **234** and could measure the deflection of the bottom surface of the cushion or foam layer **232**.

When a SAW strain gage **244** is used as part of weight sensor **200**, an interrogator **246** could be placed on the vehicle to enable wireless communication and/or power transfer to the SAW strain gage **244**. As such, when it is desired to obtain the force being applied by the occupying item on the seat, the interrogator **246** sends a radio signal to the SAW strain gage causing it to transmit a return signal with the measured strain of the spring **242**. Interrogator **246** is coupled to the processor used to determine the control of the vehicle component.

As shown in FIG. **9D**, one or more SAW strain gages **248** could also be placed on the bottom surface of a seat support pan **247** for those vehicles using this construction in order to measure the deflection of the bottom surface of support pan **247** which is representative of the weight of the occupying item to the seat. An interrogator **249** could also be used in this embodiment.

One seat design is illustrated in FIG. **9**. Similar weight measurement systems can be designed for other seat designs. Also, some products are available which can approximately measure weight based on pressure measurements made at or near the upper seat surface **236**. It should be noted that the weight measured here will not be the entire weight of the occupant since some of the occupant's weight will be supported by his or her feet which are resting on the floor or pedals. As noted above, the weight may also be measured by the weight sensor(s) **6** and **7** described above in the seated-state detecting unit.

As weight is placed on the seat surface **236**, it is supported by spring **234** which deflects downward causing cable **205** of the sensor **200** to begin to stretch axially. Using a LVDT as an example of length measuring device **220**, the cable **205** pulls on rod **221** tending to remove rod **221** from cylinder **223** (FIG. **9B**). The movement of rod **221** out of cylinder **223** is resisted by a spring **222** which returns the rod **221** into the

cylinder **223** when the weight is removed from the seat surface **236**. The amount which the rod **221** is removed from the cylinder **223** is measured by the amount of coupling between the windings **226** and **227** of the transformer as is well understood by those skilled in the art. LVDT's are commercially available devices. In this matter, the deflection of the seat can be measured which is a measurement of the weight on the seat. The exact relationship between weight and LVDT output is generally determined experimentally for this application. An alternative weight measuring apparatus will be discussed below.

SAW strain gages could also be used to determine the downward deflection of the spring **234** and the deflection of the cable **205**.

By use of a combination of weight and height, the driver of the vehicle can in general be positively identified among the class of drivers who operate the vehicle. Thus, when a particular driver first uses the vehicle, the seat will be automatically adjusted to the proper position. If the driver changes that position within a prescribed time period, the new seat position will be stored in the second table for the particular driver's height and weight. When the driver reenters the vehicle and his or her height and weight are again measured, the seat will go to the location specified in the second table if one exists. Otherwise, the location specified in the first table will be used.

The system described above is based on the assumption that the occupant will be satisfied with one seat position throughout an extended driving trip. Studies have shown that for extended travel periods that the comfort of the driver can be improved through variations in the seat position. This variability can be handled in several ways. For example, the amount and type of variation preferred by an occupant of the particular morphology can be determined through case studies and focus groups. If it is found, for example, that the 50 percentile male driver prefers the seatback angle to vary by 5 degrees sinusodially with a one-hour period, this can be programmed to the system. Since the system knows the morphology of the driver, it can decide from a lookup table or algorithm (trained or not) what is the best variability for the average driver of that morphology. The driver then can select from several preferred possibilities if, for example, he or she wishes to have the seatback not move at all or follow an excursion of 10 degrees over two hours.

This system provides an identification of the driver based on two morphological characteristics which is adequate for most cases. As additional features of the vehicle interior identification and monitoring system described in the above referenced patent applications are implemented, it will be possible to obtain additional morphological measurements of the driver which will provide even greater accuracy in driver identification. Two characteristics may not be sufficient to rely on for theft and security purposes, however, many other driver preferences can still be added to seat position with this level of occupant recognition accuracy. These include the automatic selection of a preferred radio station, vehicle temperature, steering wheel and steering column position, etc.

One advantage of using only the height and weight is that it avoids the necessity of the seat manufacturer from having to interact with the headliner manufacturer, or other component suppliers, since all of the measuring transducers are in the seat. This two characteristic system is generally sufficient to distinguish drivers that normally drive a particular vehicle. This system costs little more than the memory systems now in use and is passive, i.e., it does not require action on the part of the occupant after his initial adjustment has been made.

Instead of measuring the height and weight of the occupant, it is also possible to measure a combination of any two morphological characteristics and during a training phase, derive a relationship between the occupancy of the seat, e.g., adult occupant, child occupant, etc., and the data of the two morphological characteristic. This relationship may be embodied within a neural network so that during use, by measuring the two morphological characteristics, the occupancy of the seat can be determined.

Naturally, there are other methods of measuring the height of the driver such as placing the transducers at other locations in the vehicle. Some alternatives are shown in FIG. **10** which is a side plan view wherein two height measuring sensors **320**, **321** are shown, sensor **321** being mounted into the headliner above the occupant's head and the other sensor **320** being mounted onto the A-pillar. A sensor as used herein is the combination of two transducers (a transmitter and a receiver) or one transducer which can both transmit and receive. The headliner is the trim which provides the interior surface to the roof of the vehicle and the A-pillar is the roof-supporting member which is on either side of the windshield and on which the front doors are hinged. These transducers may already be present because of other implementations of the vehicle interior identification and monitoring system described in the above referenced patent applications. In this case, the use of both transducers provides a more accurate determination of location of the head of the driver. Using transducer **321** alone, the exact position of the head is ambiguous since the transducer measures the distance to the head regardless of what direction the head is. By knowing the distance from the head to transducer **320**, the ambiguity is substantially reduced. This argument is of course dependent on the use of ultrasonic transducers. Optical transducers using CCD or CMOS arrays are now becoming price competitive and, as pointed out in the above referenced patent applications, will be the technology of choice for interior vehicle monitoring. A single CCD array of 160 by 160 pixels, for example, coupled with the appropriate pattern recognition software, can be used to form an image of the head of an occupant and accurately locate the head for the purposes of this invention. It can also be used with a face recognition algorithm to positively identify the occupant.

FIG. **10** also illustrates a system where the seatbelt **330** has an adjustable upper anchorage point **331** which is automatically adjusted by a motor **332** to a location optimized based on the height of the occupant. The calculations for this feature and the appropriate control circuitry can also be located in control module **301** or elsewhere if appropriate.

Many luxury automobiles today have the ability to control the angle of the seat back as well as a lumbar support. These additional motions of the seat can also be controlled by the seat adjustment system in accordance with the invention. FIG. **11** is a view of the seat of FIG. **8** showing motors **481** and **482** for changing the tilt of the seat back and the lumbar support. Three motors **482** are used to adjust the lumbar support in this implementation. The same procedure is used for these additional motions as described for FIG. **8** above.

An initial table is provided based on the optimum positions for various segments of the population. For example, for some applications the table may contain a setting value for each five percentile of the population for each of the 6 possible seat motions, fore and aft, up and down, total seat tilt, seat back angle, lumbar position, and headrest position for a total of 120 table entries. The second table similarly would contain the personal preference modified values of the 6 positions desired by a particular driver.